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No. 15

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Chemistry	Mechanical Engineering	Physics
Computers	Civil Engineering	Propulsion and Fuels
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TRANSLATIONS ON USSR SCIENCE AND TECHNOLOGY

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No. 15

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CONTENTS (Continued)

CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

PROGRESS AND IMMEDIATE GOALS IN AUTOMATION OF CONTROL PROCESSES

Kiev UPRAVLYAYUSHCHIYE SISTEMY I MASHINY in Russian No 1, Jan-Feb 77 pp 3-6

[Article by Vladimir Aleksandrovich Myasnikov, doctor of technical sciences, GKNT SM SSSR [State Committee on Science and Technology of the USSR Council of Ministers], Moscow: "Advances and Immediate Goals in the Area of Automating Control Processes in the USSR's National Economy"]

[Text] "To make possible further development and to increase the efficiency of automated control systems and computing centers, uniting them logically into a single Statewide system for gathering and processing data for accounting, planning, and control. To create multiple-user computing centers." (From "Main Guidelines for the Development of the National Economy of the USSR for 1976-1980."

At the 25th CPSU Congress, in defining the main features of the development of the national economy of the USSR in the 10th Five-Year Plan, Comrade L.I. Brezhnev said, "Special emphasis on efficiency--and this must be repeated again and again--is the most important component of our entire economic strategy."

A substantial contribution to increasing the efficiency of the national economy is provided by the use of computer technology for automating control processes. Quantitative growth in product output and qualitative changes in technological processes are being accompanied by an increase in the amount of information necessary for optimum planning and control of production, and the volume of information is growing more rapidly than product output. The special commission of GKNT SM SSSR has found that at the present time the amount of information circulating in our national economy is equivalent to approximately 25 million books of 500 pages each. According to the data of Glavarkhiv SSSR [USSR Main Archives] about 60 billion written documents are originated in the country each year. Estimates have shown that in 1990 the volume of information necessary for planning and control will have increased two- to threefold.

With this situation increasing the quality of control cannot be accomplished by means of organizational measures alone, aimed at improving the control structure, eliminating multilinks, setting up associations, freeing the USSR's Gosplan and the State planning committees of individual republics from dealing with and solving petty economic problems, and the like. These measures must be reinforced by the extensive use of computers and of automated control systems created on their basis.

In the Soviet Union a definite degree of know-how has been gained in the use of computer technology for controlling technological processes and automating design operations, for operational control of production and for drawing up quotas for enterprises, for estimating balances of material resources, and for monitoring interaction between enterprises and individual industries, and the like. During the years of the Ninth Five-Year Plan more than 2,300 automatic and automated systems were put into operation for controlling complicated technological processes, enterprises, associations, and industries of the national economy.

There has been especially extensive development of automated and automatic systems for controlling complicated technological processes (ASUTP's). Over the five-year period more than 500 ASUTP's were put into operation in industry, mainly in power engineering, in ferrous and non-ferrous metallurgy, in the chemical and petrochemical industry, and in the building materials industry.

The technological level of ASUTP's has increased to a marked degree. Improved third-generation control computers like the M6000 and the "Elektronika" have been used to create them; more than 200 ASUTP's were created on their basis in 1971-1975.

An examination of ASUTP's currently in use in industry has shown their high economic efficiency, achieved owing to an increase in product output with the same capacities, to more frugal consumption of materials and energy, and to improved quality. As a result the cost of creating these systems is paid off in one to one and one half years on average.

In ferrous metallurgy automatic control of the process of smelting steel in electric arc furnaces has increased their output 3.3 percent and reduced specific power consumption 3.4 percent. Automation of control of aluminum electrolysis has made it possible to reduce specific power consumption 1.5 percent. At the Zyryanovsk Ore Concentration Plant an ASUTP has made it possible to increase extraction of basic elements from ore by 1.5 to 4 percent, to improve the quality of commercial concentrates, and to reduce the number of workers by 100.

ASUTP's have in many instances not only improved economic indicators for production and the quality of products manufactured, but have also changed working conditions and the nature of their job for workers. In the chemical and petrochemical industry automation of the control of heavy-duty and injurious production processes has freed as much as 30 percent of equipment operators at large plants and has made it possible to take servicing personnel out of areas with harmful working conditions.

Based on the know-how gained, and for the purpose of hastening the development of ASUTP's, the USSR Council of Ministers in August of 1975 issued the decree entitled "The Development of Operations for Creating Automated Systems for Controlling Technological Processes, Plants, and Production Processes," in which measures are provided for hastening the manufacture of control computers and peripheral equipment for outfitting ASUTP's. By this decree provision was made to, in the period from 1976 to 1980, increase considerably the amount of work to be done on automating complicated technological processes with the use of computer technology, and a determination was also made of the procedure for planning and financing operations for creating ASUTP's.

During the years of the Ninth Five-Year Plan about 1,400 automated systems were created for controlling associations, enterprises, and other organizations (ASUP's [automated systems for controlling enterprises]), and of this number about 500 systems were put into operation in 1975. Taking systems put into operation previously into account, at the beginning of 1976 more than 1,600 ASUP's were in operation in the country, of which 940 were operating in industry, 380 in construction, and 60 in transportation. Unfortunately, ASUP's created in the last five-year plan are based for the time being for the most part on second-generation computers, owing to a lack of third-generation machines (YeS computers).

At the Moscow "Krasnaya Roza" [Red Rose] Silk Combine imeni Rosa Luxemburg an ASUP has been created in which managerial and process control of the enterprise have been combined. By means of this system production schedules are optimized and considerable improvement in organizing workers' jobs is being made possible. Before introduction of this system a weaver working with many machines had to make regular rounds of machines to eliminate thread from breaking and other troubles which arise. In the ASUP there is a system of automatic monitoring which, when trouble occurs, displays the number of the machine and the nature of the malfunction on a graphic control panel, which has not only facilitated the weaver's work, but has also made it possible to increase the number of machines which she maintains. These measures in conjunction with the installation of new looms have made it possible to reduce the number of service personnel in the weaving section by a factor of 2.6.

During the years of the Ninth Five-Year Plan GKNT SM SSSR, with the participation of various ministries and departments, did a considerable amount of work on creating and disseminating method handbooks and standard project solutions (TPR's) for the development and introduction of different ASU's [automated control systems]. Their use in creating ASU's has made possible a reduction in development time, a 20 to 30 percent reduction in cost, and an increase in the scientific and technological level of systems. Many of the TPR's have been published for mass circulation and have been recommended for extensive use in planning organizations. In the last five-year plan these TPR's were used in creating more than 400 ASU's for enterprises and associations in instrument making, machine tool building, agricultural machine building, the motor vehicle, and other branches of industry.

There have also been considerable improvements in the area of creating and putting into operation automated systems for controlling industries (ministries) and other central organizations. At the present time industry-wide automated control systems (OASU's) are in operation in 34 all-Union and Union republic industrial ministries. In addition, 120 systems have been created in ministries of Union republics.

The range of problems which can be solved in OASU's has been expanded considerably. In particular, in some OASU's there is a system for calculating many variants of annual and five-year quotas for the industry.

In Mingazprom [Ministry of the Gas Industry] by means of an OASU calculations are being made in the area of longterm and current planning, of operational management of enterprises, of finance and bookkeeping, and of personnel planning and recordkeeping. The Subsystem for Supervisory Control of the Unified Gas Supply Network (the ASDU YeSG) is making it possible by means of the computer to gather and analyze accounting and planning data, to make optimization calculations for loading gas supply mains and to keep consumer accounts. The annual savings from introducing this system has been about 43 million rubles, with total costs for its creation amounting to 11.3 million rubles.

In 1975 work was completed on the creation of the first phase of ASU's in a number of central agencies, such as the Automated System for Planning Estimates (ASPR) of the USSR's Gosplan, the Automated System for State Statistics (ASGS) of TsSU SSSR [Central Statistical Board of the USSR], the OASU of the USSR's Gossnab and of Goskomizobreteniy [State Committee for Inventions], and the Automated System for Data Processing of Goskomitet Tsen [State Committee for Pricing] (ASOI Tsen).

In the OASU of the USSR's Gossnab computer calculations are being made to optimize schedules for delivering to enterprises about 500 million tons of ferrous and non-ferrous metals, building materials, cement, paper, timber, and chemical and petroleum products. On this basis an optimized freight flow system has been developed, making it possible to reduce the volume of freightage by approximately 20 billion ton-kilometers and to release more than 10,000 railroad cars from daily 24-hour rounds. The annual savings in transportation costs has been about 40 million rubles. Computer calculations for disposition of orders have been conducive to an improvement in the employment of the capacities of metallurgical plants and to a consequent increase in the output of non-ferrous tubing and rolled stock of three to five percent.

During the last five-year plan obsolete second-generation computers were removed from production (the M-222, "Ural-11," "Ural-14," "Promin'," and "Minsk-32"). In 1975 the manufacture of the YeS-1022 computer began (to replace the YeS-1020) and the YeS-1033 (to replace the YeS-1030) will be manufactured in 1977. The modernized models are faster and have an expanded main memory and respond better to the growing requirements of ASU's. There has been some expansion of the list and increase in the production of peripheral equipment, such as tape stores, input-output units for punched cards and punched tape, and printers.

In recent years there has been improvement in the structure and number of programs delivered to manufacturing plants as part of the computer package. In 1975 development work was completed on the OS-4.0 improved operational system, which makes it possible to hook up to the computer and service many users supplied with alphanumeric graphic displays. This operational system also makes it possible to use programs written in algorithmic languages.

One of the most promising trends in the development of general software for modern computers is the development of program packages which expand the functions of the operational system. In this regard mention should be made of the KAMA (for controlling remote processing of data) and the OKA (for controlling data bases) packages developed in 1976.

The efficiency achieved from using computer facilities depends to a considerable extent on the state of perfection of methods of developing programs. Worthy of special attention is the program package developed in 1976, making it possible to automate the process of developing programs--the RTK package.

A specialized organization called "Tsentrprogrammsistem" [Program Systems Center] has been created to distribute packages of applied programs, to offer assistance to users in putting them into operation, and to debug programs on the basis of know-how gained from experience in using them.

To increase the efficiency achieved from using computers an organization called "SoyuzEVMkompleks" [Computer Complex Alliance] has been formed, whose job is to provide for maintenance and overhauling of computers in the Unified System. A similar organization has been created for maintaining computers of the M6000 and M7000 type, and others.

In 1971-1975 more than 126,000 specialists with a higher education and 49,000 specialists with a mid-level specialized education were trained for jobs in the field of computer technology and ASU's.

In spite of a set of measures making it possible to raise the use of computers in all spheres of human activity to a higher degree of quality, there were serious deficiencies in this area in the Ninth Five-Year Plan.

Medium-efficiency computers predominated in the structure of computer hardware manufactured. The output of small computers and high-efficiency computers of the YeS-1050 type was insufficient, and there were delays in the development of the YeS-1060 with an operating speed of 1.3 million operations per second. The output of peripheral equipment--magnetic disks, printers, data input-output units, user hookups, and the like--lagged considerably behind the demand. Computing centers experienced great difficulty in providing computers with machine information carriers.

The problem of providing computing centers with the necessary equipment and materials was made more acute by the fact that their distribution was carried out by several organizations and was but slightly tied in with plans for the creation and development of computing centers and ASU's. The application of computers was in a number of instances not accompanied by improvement in the control structure, which also reduced the effectiveness of using expensive computer hardware. Part of the ASU's was developed by small organizations having neither suitable development personnel nor the necessary know-how. The systems which they created are capable of solving, as a rule, only the simplest accounting problems and do not provide the savings necessary. Work was also slow in the development of standard project solutions oriented toward the use of third-generation computers.

The "Main Guidelines for the Development of the National Economy of the USSR in 1976-1980" have provided for a growth in the output of computer hardware of a factor of 1.8. Thirteen hundred ASUTP's will be put into operation, the number of enterprises and associations at which ASUP's will be created will increase by a factor of 1.5, and OASU's and systems operating in central agencies will be developed further.

This scale of operations requires an increase in the sense of responsibility of organizations which make possible the development, manufacture, and employment of computer hardware. The USSR's Gosplan, the State Committee on Science and Technology of the USSR Council of Ministers, and the corresponding ministries and departments have taken a number of measures to guarantee an effective solution to the problems in this area facing the national economy.

Plans have been made to increase the output of modified computers for the Unified System of the YeS-1022 and YeS-1033 type and to increase the output of the YeS-1050 computer. Production will also be set up for further improved computers for the Unified System with an operating speed of four to five million operations per second.

As far as auxiliary memory units are concerned, plans have been made to set up for the production of high-capacity magnetic disks (100M bytes and more) and for the mass production of alphanumeric and graphic displays. There will be expansion in the outfitting of computers with packages of disks, tape drives, rapid printing units, and displays.

For setting up multiple-user computing centers plans have been made for the mass production of an entire package of input-output units, different modifications of user's stations, adapters, modems, and the like. At the end of the 10th Five-Year Plan recording of primary data on magnetic minicassettes will have been introduced on a wide scale, which will make it possible, first, to reduce drastically the consumption of paper for punched cards and tape and, second, to increase the reliability of data storage. This method of recording information will also make it possible to dispense with superfluous mechanical equipment used presently and also to avoid the losses entailed in preparing and reading punched cards and tape.

The main problem in the field of small (control) computers is to extend the number of different types and to increase the operating speed of the older models to two to three million operations per second. In conjunction with

CEMA countries a work program is being carried out to create a new series of machines, including five types of processors with an operating speed of from 200,000 to one million operations per second, which will make it possible to use them more efficiently and logically for automating complicated technological processes.

An important step in improving electronic machines of all classes is the creation of integrated circuits with large-scale integration (more than 10,000 components in a crystal). Integrated circuits of this sort are making it possible to create microprocessors which are opening up extensive possibilities for automating the control not only of complicated, but also of simple technological processes, in particular the control of individual machine tools, plants, and the like.

Special attention will be devoted to creating multiple-user computing centers, making it possible to use computers in the most economical way.

The distribution of computer hardware and packages of peripheral equipment and auxiliary equipment between computing centers and ASU's it makes good sense to concentrate in the hands of the USSR's Gosplan, and the distribution of operating materials and equipment for supplementary outfitting of computing centers and ASU's undergoing modernization in the hands of the USSR's Gossnab.

The 25th CPSU Congress has set heavy quotas for expanding the output and making efficient use of computer equipment in the national economy. It is the duty of all managers and specialists in the area of developing, manufacturing, and employment of computer hardware to fulfill these quotas with honor.

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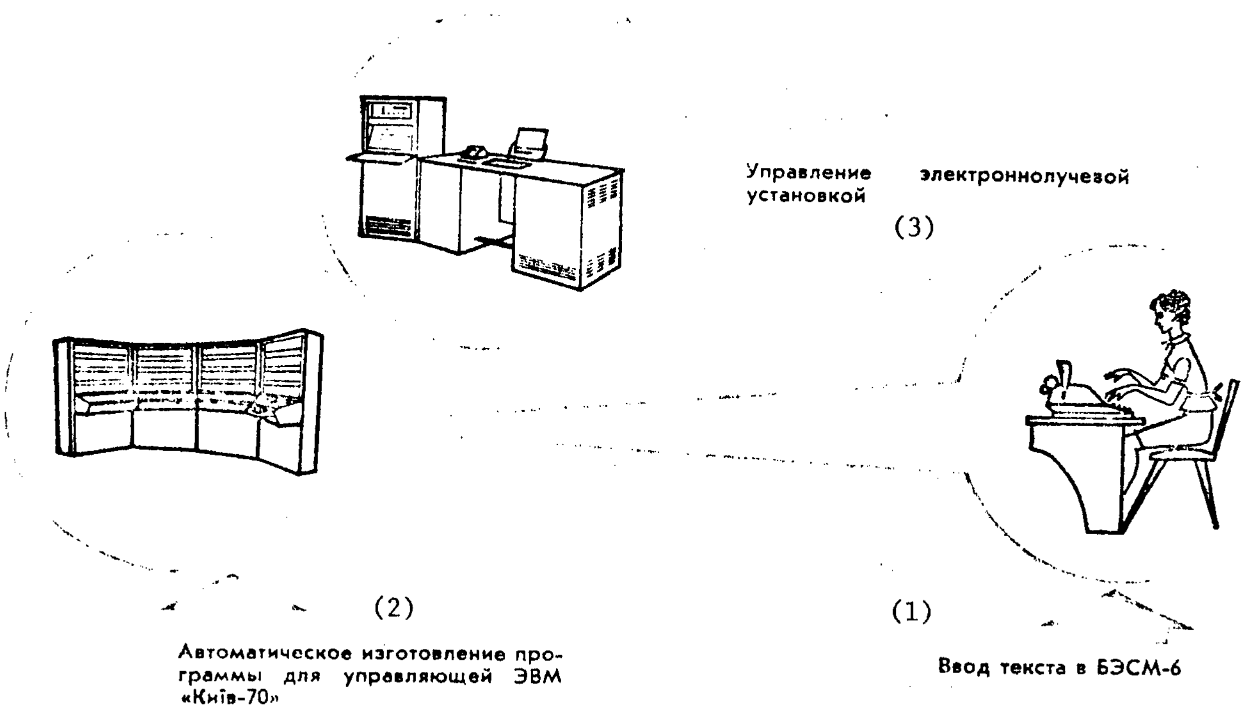
CSO: 1870

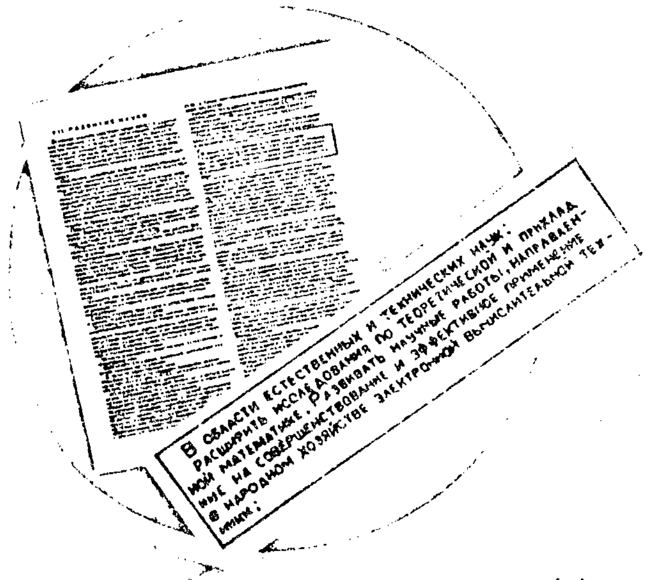
COMPUTER-CONTROLLED ELECTRONIC LITHOGRAPHIC PROCESS

Kiev UPRAVLYAYUSHCHIYE SISTEMY I MASHINY in Russian No 1, Jan-Feb 77 inside back cover

[Text] There was an unusual exhibit in the demonstration hall of the Order of Lenin at the Ukrainian SSR Academy of Sciences Institute of Cybernetics on the evening of the scientific session, which took place in Kiev in December 1976, devoted to the 25th anniversary of the date when the first domestic computer was put into operation. Each participant in the session was able to read by means of an electron microscope the entire text of the seventh section of the "Main Guidelines for the Development of the National Economy of the USSR for 1976-1980" approved by the 25th CPSU Congress, written on a crystal measuring 0.1 square millimeters in area.



[Key on following page]



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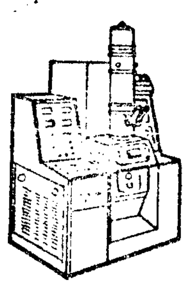

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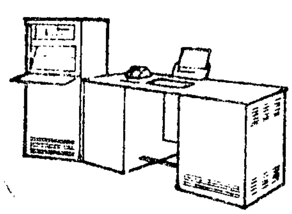

(3)

Управление электроннолучевой установкой

[Key on following page]

Key:

1. Entry of text into a BESM-6
2. Automatic writing of program for the "Kiev-70" control computer
3. Control of electron beam unit
4. Automatic writing of text on the crystal by the electron beam
5. Recording density--70,000 characters per square millimeter. Line breadth--0.5 micron. Height of character--3 microns. Excerpted text fragment magnified 240,000 times. With this recording density the text of all 30 volumes of the BOL'SHAYA SOVETSKAYA ENTSIKLOPEDIYA [Great Soviet Encyclopedia] can be placed on an area of 22 square centimeters. Unbelievable!

The text was written with an electron beam controlled by a "Kiev-70" computer using a program written automatically by a state-of-the-art automated system for designing computers. For producing the text use was made of an ultrafine electronic lithographic process developed at organizations of the USSR Ministry of the Electronics Industry, which would be impossible to perform without using computer technology.

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SHORTCOMINGS IN OIL INDUSTRY AUTOMATED SYSTEMS

Baku BAKINSKIY RABOCHIY in Russian 6 May 1977 p 2

/Article by N. Seidov, inspector from the Azerbaydzhan SSR People's Control Committee; A. Minchuk, chief of the Information Systems Laboratory of SRPI Neftekhimavtomat; and Z. Kuperman, BAKINSKIY RABOCHIY public affairs correspondent: "'Trivia'--Not at all Trivial: Or, How Modern Control Means Coexist with Antiquated Work Methods at Azneft'"/

/Text/ The decisions of the 25th CPSU Congress assigned a large role to further developing and increasing the efficient utilization of automated control systems (ACS) and computer centers. The "Basic Guidelines for USSR National Economic Development for 1976-1980" set before the petroleum industry the task of continuing the technical reequipment of the industry, complete automation of technological processes and introduction of ACS in the oil fields.

The introduction of the first line of ACS was basically accomplished during the last five-year plan in the production association Azneft' /State Association of the Azerbaydzhan Petroleum Industry/. The massive introduction of remote control and automated systems was begun even earlier. The republic's petroleum workers were pioneers in this area. They made the AGM /expansion unknown/ remote control system; from a control console remoted tens of kilometers from the oil well, this system facilitated the determination of its output and timely "spotting" of deviations in extraction technology. Control over deep-well pump operations was accomplished with the help of the CHTP /expansion unknown/ systems which they developed and introduced. Over 8,000 Azneft' oil wells are equipped with these automated systems. But, this equipment is frequently not used efficiently enough. We calculated the utilization rate for just the second of these systems in three Oil and Gas Production Administrations (OGPA). It was 88 percent in Leninneft', 92 percent in Kirovneft' and only 67 percent in Karadagneft'. For the last OGPA the AGM system utilization rate was...only 20 percent. Overall, the index barely topped 50 for the association. True, it is necessary to point out that this data treats a difficult period for normal automated systems operations--20 days in February. They are higher at other times. But, the fact that automated systems "efficiency" rates depend, as we saw, on the weather shows the apparent lack of reliability in their use.

Now let's follow the path of the information received from the automated systems. It is accumulated in the RETS's /Regional Engineering and Technical Service/. From here it goes to the OGPA, to the Central Engineering and Technical Service, and then, to the computer center. To a great extent the reliability of these communication links determines the quality of ACS operations. But, as the facts show, it is not high. The reason is that, on the one hand, there is no data transmission equipment at the RETS's and, on the other, there are no special communication channels. Therefore, information which is automatically derived is transmitted further by telephone or delivered by courier. Furthermore, this takes a lot of time and the reliability and practicality of data transmission suffers.

Further, according to the plan developed by the SRPI Neftekhimavtomat /Scientific Research and Planning Institute for Complex Automation of the Petrochemical Industry Production Processes/, information from the OGPA's to the Multiple-User Computer Information Center (MCIC) must be routed along two telegraph channels and one telephone communication control channel. But, the lines are only laid from Leninneft' and Kirovneft' OGPA's. And even here the telegraph cables are "not operational." What are the reasons for this situation? The customers, the workers from the radiotelephone communications office of the Azneft' Association, cite the poor work of the contracting organization--CIA-4 /Construction and Installation Administration/ of the Azneft' Construction Trust--and of the subcontractor--Transcaucasus Installation Design Administration. And these organizations advance their arguments...

But, meanwhile, the whole point of the matter is that communication between the OGPA's and the computer center is accomplished on a telephone line which was laid for entirely different purposes. And this stirs up a lot of "trouble": the efficient utilization of automated systems declines, information is frequently distorted and the impracticality of such communication is further aggravated by the fact that the operators must spend a lot of time rechecking the data. The result of all this (perhaps it will seem unexpected to someone) is natural: the petroleum workers lose faith in the validity of information received in this manner and they are inclined to obtain it the old way. Drive over, take a look--and that's the entire method...

The problem of premises for equipment installation is critical. Not all the OGPA's took care of allocating or constructing such premises. Why, the building for the Azneft' computer center has already been under construction for many years and the end is still not in sight. The building frame was erected by CA-84 /Construction Administration/ of Trust No 8 of the republic's Ministry of Industrial Construction; the Azneft' Construction Trust was commissioned to complete the construction. But, during the facility transfer substantial defects were discovered (three years ago). Naturally, the guilty party, Trust No 8, was charged with clearing up the defects. Finally, last year, a plan for reinforcement of the building was formulated. However, it still has not been coordinated with all interested organizations. While the procrastination in commissioning the main building continued and, apparently, continues, two auxiliary buildings were built next door. The MCIC with its three electronic computers, teletype and other equipment is located in them. Is it necessary to point out that the work conditions here are not in line with the high level of electronic computer technology; after all, it requires special conditions: a specific temperature and humidity which ensures operational accuracy and longevity (and this is very important for such expensive equipment). Of course, these conditions do not exist in the building where they are located. It is not hard to draw conclusions from this.

In spite of all this confusion, the ACS at Azneft' is still successfully solving a number of problems: it processes information on the status of the oil wells and on extraction and output of oil and gas, it keeps track of underground repair work, it compiles optimal operational requests for preventive maintenance, etc. Overall, the solution of 21 problems was mastered at the MCIC. It is planned to double the number of problem solutions. But, it must be pointed out that these problem solutions are directed only at extraction problems. Work on the solution of drilling problems is proceeding half-heartedly, the "Construction" subsystem is still not operational and so forth.

In the near future another, more powerful electronic computer will be added to the three now at Azneft' and this will naturally increase the petroleum workers' possibilities for solving the complex problems of controlling both the association's enterprises and ancillary production. The realization of these possibilities depends to a great extent on how successfully the ACS "bottlenecks" are eliminated.

Let's cite another factor which has a negative effect on the solution of the problem of overall ACS introduction--the personnel problem. A good collective of skilled engineers and operators was formed at the MCIC. But, overall, all is not well with ACS service personnel. Turnover is high. In our opinion, the main reason for this is the poor economic incentive system. The work of computer and teletype operators is fairly strenuous and requires highly specialized knowledge, but the pay does not always correspond to the workers' skills. It is especially bad for ACS peripheral equipment personnel. Workers' skills in these services frequently do not meet stated requirements. The technical equipment outage logs contain many entries on shutdowns due to operator incompetence. Even a simple misalignment of the papertape causes large equipment downtimes and because of such trivia an expert is specially called in from the peripheral equipment maintenance group. And, you know, one must drive tens and sometimes hundreds of kilometers to reach several of the OGPA's. Now, really, is this expeditious?

There is no doubt that the development and improvement of ACS in the Azneft' Association will be of great national economic importance; it will ensure the successful solution of the problem placed before the petroleum workers: stabilize the level of oil production and create reliable bases for its growth.

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UDC 621.372.837.4

ELECTRICALLY CONTROLLED MICROWAVE SWITCHES USING TRANSISTORIZED DIODES, A SURVEY

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[Article by M. Ye. Il'chenko, V. G. Osipov]

[Text] A study is made of the principles of the construction of the multichannel electrically controlled commutation units in the microwave range based on the semiconducting diodes. A classification and the system of parameters of multichannel switches using transistorized diodes are presented. The basic characteristics obtained as a result of the development and investigation of the switches are presented.

The electrically controlled microwave switches using semiconductor diodes proposed at the end of the 1950s [1, 2] at the present time constitute a new class of commutation devices and in the last 10 to 15 years they have come from the first laboratory developments to series precision devices, the use of which predetermines the possibility of constructing an entire series of modern microwave systems. The use of the semiconductor microwave switches in many cases turns out to be more expedient than the use of the switches with the application of ferrites, a gas discharge plasma, or electromechanical elements. This is caused by the fact that the semiconductor switches require comparatively low power of the controlling source (no more than 100 milliwatts)*; they are quite compact, they have small weight and high speed (from fractions to nanoseconds to tens of microseconds), they are quite wideband (covering a range of up to several octaves), they have long service life and high reliability.

As the switches it is possible to use various semiconducting diodes: with p-n junction, with the Shottky barrier, with the p-i-n-structure and also the avalanche drift diodes and Gunn diodes. The diodes with the p-i-n-structure are distinguished by the greatest technical possibilities on the basis

* However, in certain cases, it is necessary to use accelerating and elongating pulses in order to increase the speed of the switches, and the power of the pulse source can be an order higher

of the known peculiarities of [3-6]. The characteristics of the switches based on the p-i-n-diodes are not optimal in all respects, but they insure an acceptable compromise in satisfying the contradictory requirements imposed on the commutation devices of modern microwave systems. There are reports [2, 3] on the development of microwave switches in the meter, centimeter and millimeter wave bands based on p-i-n-diodes with pulsed operating power from several watts to kilowatts.

The growing requirements on the wideband nature of the systems in which the microwave switches are used have given rise to the development of the jacketless planar p-i-n-diodes and surface oriented diodes with bar outputs suitable for creating hybrid microstrip microwave integrated circuits [5, 8, 9].

In this paper a study is made of the principles of the construction of the commutation devices in the microwave range based on the p-i-n-diodes. The classification and the system of parameters of the microwave switches using semiconductor diodes are presented, after which the basic versions of the construction and standard attainable parameters of the switches are analyzed.

The microwave switches can be constructed using the parallel, series and combined inclusion of the switching diodes based on all of the existing microwave transmission lines depending on the complexity of the structure of the switch and the necessity for certain regulations to compensate for the spurious parameters of the diode imposing restrictions both on the magnitude of the losses introduced and the decoupling and on the pass band width. The type of transmission line is selected beginning with the given frequency band, the switchable power level and the conditions of application. In Table 1 we have the schematic of the possible classification of the microwave switches on the switching diodes.

When using the p-i-n-diodes as the switching elements of the microwave channel, the electrical parameters of the devices depend on the parameters of the used diodes and on their circuit diagrams. The microwave commutation devices can be created on the basis of the direct or inverse system for using the switching diode [11, 12]. For the case of the Shottky inclusion of the diode, the maximum introduced attenuation when using the direct circuit corresponds to the feed of a positive bias to the diode; when using the inverse system, the maximum introduced attenuation is observed for feeding an inverse bias to the diode. In this case, use is made of the natural series resonance of the switching diodes. The use of the p-i-n-diodes with ordinary jackets in a straight circuit in the shortwave part of the centimeter band has been held up to a significant degree by the opinion of the significant role of the necessity for successive resonance. This has led to the development of special resonating diodes, the parameters of which were selected so that during shunting inclusion of the diode in the waveguide of diminished height in two working states on the middle frequency band, the resonances of the series and parallel types are insured without the application of tuning elements [12, 13]. The use of the p-i-n-diodes in the inverse system leads to the fact that, for example, in protective devices in the high power level regime, the diode operates under the most serious conditions, being under high microwave voltage. The increase in thickness of the i-layer required to raise the breakdown voltage leads to growth of the inertia of the switch.

Table 1

Classification of the Switches

Item No.	Classification criterion	Types of switches
1	Type of switching diode	Switches with diodes of p-n-junction, Schottky barrier, p-i-n-structure and also the avalanche drift diodes and Gunn diodes
2	Operating range	Narrow band (with a band less than an octave), wide band (with a band of an octave or more), tunable (narrow band switches tunable in a wide frequency band [10]).
3	Number of switchable channels	Switches of the following type: $I \leftrightarrow n$, one output channel of which can be jointed to one of the n output channels; $I \leftrightarrow n/m$, one input channel of which is joined to the m output channels from the total number of n output channels; $\ell \leftrightarrow n$, one of the ℓ input channels of which is connected to any of the n output channels; 2 [illegible] n, in which the joining of the two arbitrary channels made up of a total number of channels n is carried out; n x n, in which the connection of each of the n input channels is made with one of the n output channels.
4	Type of transmission line	Switches using the rectangular, П and H type waveguides, coaxial, strip, microstrip, two wire and the multiwire connected lines.
5	Method of including the switching diode in the transmission line	Switches based on the series, parallel, and parallel series switching of the diodes.

The version of the use of the diode in the direct system will be of great interest for the commutation of high microwave power levels and also for the creation of low inertia antennas switches.

In references [14, 15] the possibility of the application of the standard resonance diodes in the waveguides which is executed by the direct scheme and free of the deficiencies of the inverse which was demonstrated. The mean operating frequency of these switches can be close to the frequency of the natural series resonance of the diode or even exceed it.

Table 2

System of Parameters and Microwave Switches with Semiconducting Diodes

Parameter group No.	Name of parameter group	No. of the parameter	Name of the switch parameters
1	Frequency amplitude characteristic parameters	1.1	Operating frequency range
		1.2	Overlap coefficient of the band (for the wide band switches)
		1.3	Band width of the operating frequencies (for the narrow band switches)
		1.4	Introduced losses
		1.5	Decoupling of the disconnected channel with the switch input
		1.6	Decoupling of the input (output) channels of the switch
		1.7	Voltage standing wave coefficient of the input (output) channels of the switch
2	Parameters of the control circuits	2.1	Open diode control current
		2.2	Bias voltage of the open diode
		2.3	Bias voltage of the closed diode
		2.4	Current amplitude of the accelerated pulses
		2.5	Voltage amplitude of the elongating pulses
3	Parameters under conditions of application (operating parameters)	3.1	Admissible average microwave power
		3.2	Admissible pulse microwave power
			Switching time
			Commutation frequency
		3.3	Operating temperature range
		3.4	Admissible temperature range
		3.5	
		3.6	
		3.7	Variation of the introduced losses in the operating temperature range
		3.8	Admissible mechanical effects
		3.9	Admissible climatic effects (moisture, and so on) in the operating and non-operating states of the switch
4	Structural parameters	4.1	Waveguide cross section or coaxial split
		4.2	Characteristic resistance of the transmission lines
		4.3	Overall dimensions
		4.4	Structural parameters
5	Additional parameters	5.1	Service life
		5.2	Guaranteed failsafe operating time

Thus, the use of the diodes with housings of the ordinary types at high frequencies and the selection between the direct and inverse systems are limited not by the phenomenon of the successive resonance but basically the parameters of the semiconducting structure.

For a comparative estimate of the various structural designs of the microwave switches and also for estimation of the technical possibilities of certain switches under the conditions of application it is of interest to use a single system of switch parameters on the switching diodes.

In Table 2 we have such a system in which all of the parameters of the switches are classified with respect to several groups. Let us consider in more detail a number of parameters which are of the greatest practical interest.

The operating frequency band of the microwave switches in the case of using the resonance diodes and the diodes with significant reactivities of the case is limited. The systems with the series and series parallel inclusion of the caseless and the surface oriented diodes in the microstrip lines have the greatest wide band nature.

The introduced losses and decoupling of the nonoptimized microwave switches with semiconducting diodes determined by the parameters of the diodes used and the selected transmission line. The practical use of these switches, which are the most wide band, turns out to be expedient on frequencies where it is possible to neglect the reactants of the switching diode. The methods of designing wide band switches based on diodes with significant reactances based on using the properties of low frequency filters on concentrated elements and band filters on distributed elements are known. The problems of the design and analysis of such switches can be solved completely at the present time only by computer. The optimized switches have significantly better parameters at the optimization frequency, but the switches are usually narrow band. The theory of optimal design of such switches has been quite well developed [3]. For the optimized switches with identical introduced losses in the equivalent states there is a limit of introduced attentuation defined by the quality of the diodes used.

The limiting value of the input power control body microwave switch depends on the properties of the specific device and the limiting admissible values of the microwave current $J_{m\ ad}$, the voltage $U_{m\ ad}$ and the dissipated power P_{dis}. The relation between $J_{m\ ad}$, $U_{m\ ad}$, P_{dis} and the limiting admissible value of the input power can be found in the general case if the parameters of the equivalent circular device and the diode itself are known.

For the mutual switching devices of the reflecting type, the estimate of the limiting admissible level of the mean input power can be made using the following expression [16]:

$$|\dot{\Gamma}_{xx} - \dot{\Gamma}_{\text{кз}}| = U_{m\,ad} J_{m\,ad} / 2P_{inp}$$

where $\dot{\Gamma}_{xx}, \dot{\Gamma}_{\text{кз}}$ are the complex reflection coefficients at the input of the switch on meeting the corresponding return and direct biases to the diode. If several diodes are used in the switching circuit in series, parallel mixed connections, the limiting power of the switch can be increased proportionally to the number of diodes used. Here it is necessary to note that the optimal diagram of the switch from the point of view of the minimum introduced attenuation is not in the general case optimal in the sense of the maximum limiting power for the least number of diodes.

The use of the p-i-n-diodes for constructing the microwave switches is necessary for the level of switched power on the order of one watt. This imposes significant restrictions on the switching speed which must be considered when selecting the switch circuit. The switching time in this case is determined by two factors: the reactive parameters of the switch circuit and the diode and also the duration of the processes of accumulation and resorbing of the moving charge carriers into the semiconducting structure. The switching time determined by the reactive parameters of the circuit and the diode is hundredths of a nanosecond for the microwave switches. The switching time determined by the transient processes in the p-i-n-structure is several orders larger for the usually used diodes, and it determines the speed of the switch. It must be noted that the switching time can be appreciably less on injection of the charge than on the resorption of it [17]. This characteristic feature must also be considered when selecting the switch circuitry. In order to accelerate the switching processes, the low amplitude direct current and return voltage pulse feed is used operating only in the time compared with the duration of the transient process.

Let us proceed to the discussion of the basic circuits for the contruction of the multichannel microwave switches based on the semiconducting diodes.

In Figure 1 we have various versions of the circuits for constructing the two channel switches. The feed circuit elements for the controlling bias and all of the figures, except 1 a, b have not been provisionally demonstrated. The more complex switching structure can be obtained either by a simple increase in the number of channels or by combining the two channel switches*.

The switch is found to be the most compact in the case of using series inclusions of the diodes in a break in the central conductor of the output lines in direct proximity to the branch point of Figure 1, a. The wide band nature of this split is limited by the reflections from the elements of the feed circuit for the controlling bias and the necessary decoupling of

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* It must be noted that for construction of the complex commutation structures there are also special matrix methods of constructing the switches which are not considered in the given paper.

the disconnected channel. The difficulties connected with the transfer of heat from the diodes do not permit us to use this version of inclusion of the diode when switching the high power levels. For the construction of the switches with the series inclusion of the diodes, in addition, the special diodes are needed with radiant output suitable for building the coaxial or microstrip lines into the break in the central conductor. The use of the series inclusion of the diodes for construction of the switches in the short wave part of the microwave band is connected with the development of the surface oriented p-i-n-diodes with a capacitance of the junction less than 0.5 picofarads [8, 9, 32].

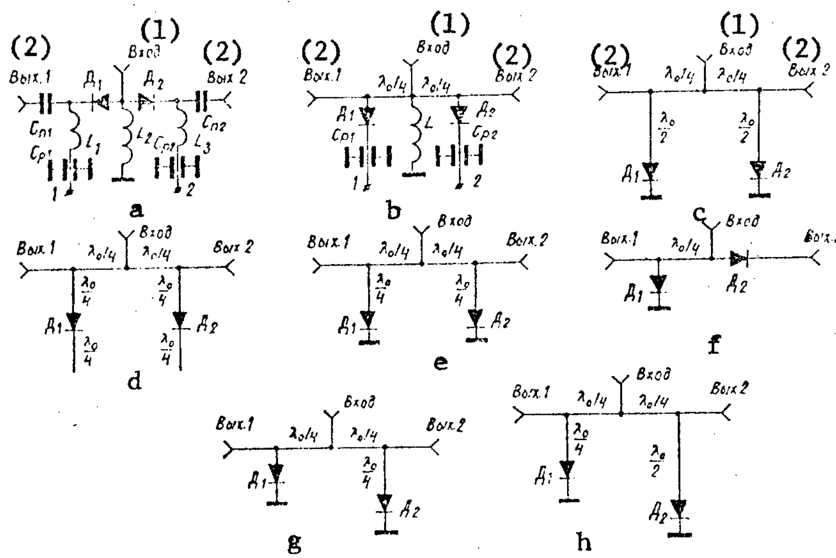


Figure 1. Basic diagrams of microwave switches using single lines.

Key: (1) input
(2) output

The advantages of the series inclusion are opened up most completely when designing the switches in the form of hybrid and monolithic integrated microwave circuits. The basic restrictions of the operating frequency range in this case is in a number of cases a significant capacitance of the diodes which does not insure the required decoupling of the disconnected channel at high frequencies. The location of the parallel included diode polarized in the return direction and having insignificant direct resistance between the series included diode permits a significant increase in the coupling [21, 22, 33-36]. The integrated circuit equipment in this case permits compensation of the reactivity of the diodes on inclusion of them in the low frequency filter circuit, the cutoff frequency of which lies beyond the limits of the operating band of the switch. The analysis of the switches with the series-parallel included diodes, the methods of synthesizing them with respect to introduced losses in the transmission regime and also with respect to the level of the required decoupling are presented in [35, 36].

Whereas the requirements of small introduced power, large decoupling of the disconnect channel and high switchable power level are imposed on the switch, the most acceptable turns out to be parallel inclusion of the diodes in the basic line or the use of shunting loops with diodes. The simple and compact switch of this type is the switch with parallel inclusion of the diodes in the output arms of the nondirectional branch of the transmission line at a distance it is a quarter of a wave length from the branch point (Figure 1, b). The direct use of this version of inclusion of the diodes to a significant degree limits the operating frequency range. Therefore in [38] the principle of expansion of the transmission band of the multichannel switches is proposed which is based on using the properties of the band filter with the quarterwave loops. This filter comprises the quarterwave loops included in the transmission line after quarterwave intervals. The basis for this principle is replacement of one of the quarterwave loops by the quasiconcentrated loop which comprises the capacitance of the reverse bias diode and the shortcircuited tuning loop. The elements of the quasiconcentrated loop are selected so that it will be equivalent to the initial quarterwave loop of the filter. The data from the calculation of the parameters of the quasiconcentrated loops are presented in [39, 40].

The diagrams of the switches with the diodes included at the ends in the form of a load (Figure 1, c) or in the break of the central conductor, the half wave loop (Figure 1, d), although more awkward, insure the possibility of improving the characteristics of the switches with appropriate selection of the characteristic resistance and the length of the loops and also they permit an increase in the level of commuted power [19]. The quarterwave shunting loops in the switch circuit depicted in Figure 1, e are used for inversion of the impedance of the diodes. With this inclusion of the diodes the feed of the return controlling bias to one of the diodes leads to blocking of the channel in which this diode is located. As a result of the geometric symmetry of the channels of the investigated circuits of the switches are identical. A common deficiency of these circuits is the fact that the feed of the two separate control biases (current and voltage) is simultaneously necessary and that the power of the control source is required continuously.

The circuits of the switches depicted in Figure 1, f, g, h [17, 18] are of practical interest. In order to connect the second channel to the input, it is necessary to feed a positive control bias to both diodes of the switches executed by the diagrams in Figures 1, f, g, and for the switch executed according to the diagram in Figure 1, h, the return control bias. Thus, in the given case the control bias input common to both diodes is possible. In addition, these switches exhibit different speed on switching the channels as a result of the above-noted different speed of the p-i-n-diodes on injection and resorption of the charge.

The diagram of the switch using the quarterwave directional responders (Figure 2, a), although it is distinguished by some relative band width, is rarely used as a result of the difficulties connected with feeding the control bias, awkwardness and nonidenticalness of the channels. The analogous deficiencies are also characteristic of the switch with the ferrite circulator (Figure 2, b), but it is necessary to note that for the construction of the two-channel switch in the given case one p-i-n-diode is necessary.

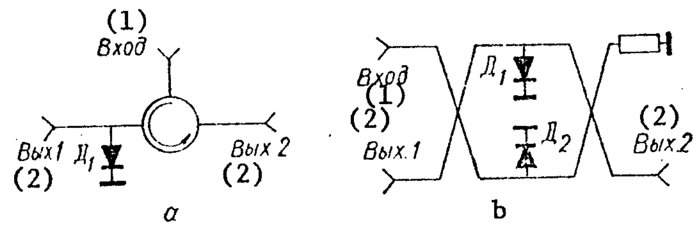


Figure 2. Hybrid circuitry for the microwave switches based on the circulator (a) and 3-db directional responders (b)

Key: (1) input
(2) output

The general problem when constructing the microwave switches is the practical realization of the feed of the control bias to the semiconductor diodes. Two possible versions of the construction of the bias circuits are presented in Figure 1, a and 1, b. The basic requirement on the elements of the bias circuit is the requirement of the minimum effect on the transmission of the microwave signal. The duct capacitors C_{π} insuring decoupling of the control circuit with the external circuit with respect to the control current can be executed in the form of a gap in the central conductor [11]. When using the microstrip lines, the duct capacitors are placed above the gap in the central conductor. The capacitor plates are perpendicular to the central conductor. These capacitors can provide the voltage standing wave coefficient no worse than 1.05 [20]. The rated values of the capacitances C_{π} and C_p are selected from the condition of the maximum permissible reflection Γ^p_{max} introduced into the channel [8]

$$C_{п} \geqslant 1/2\omega Z_0 \Gamma_{max} \quad C_{р} = \geqslant Z_0/2\omega Z^2_{ш} \Gamma_{max}$$

where Z_0 is the characteristic resistance of the line; $Z_{ш}$ is the characteristic resistance of the loop playing the role of a choke; ω is the minimum value of the frequency in the operating band.

In the case of use of a helical inductance as the choke, the reactance of the separating capacitor C_p must be appreciably less than the reactance of the inductance.

In the longwave part of the cycle wave band, the single layer mounted inductance coils, chokes with ferrite cores and in some cases thin-film resistors [21, 24] operate as the high frequency chokes. The best results can be obtained with the mounted single-layer coils. Although in [23] that for this inductance coil 1.0 mm in diameter made of wire 0.08 mm in diameter and 80 mm long, series resonance was observed on a frequency of 2.5 gigahertz, the authors of [21] state that for a wire diameter of 0.05 mm these inductances can be made for operation in the frequency band up to 18 gigahertz. In [37] the microstrip device is discussed which insures a short circuiting of the inside wire to the case by direct current and insures energy transmission in the frequency range of 2 to 12 gigahertz which is a highfrequency filter with critical frequency below this range.

The use of the quarter-wave short-circuited lifts with $Z_{ш}$, equal to the resistance of the basic line Z_0 as the high-frequency chokes gives introduced losses of 0.25 decibels on multifrequencies of the octave band. In order to decrease the reflection and expand the frequency band, it is necessary to use loops with large $Z_{ш}$. The introduced losses of this loop are as follows:

$$L = 10 \lg\left[1 + \left(\frac{Z_0}{Z_{ш}} \operatorname{ctg} \frac{2\pi}{\Lambda} l\right)^2\right],$$

where ℓ is the loop length; M is the wavelength in the line.

If f_1 and f_2 limit the frequency band in which the introduced losses do not exceed some given amount L, then the overlap coefficient with respect to the band $K_{пер} = f_2/f_1$ is defined by the following expression [11]:

$$K_{пер} = \pi \left[\operatorname{arc\,tg}\left(2 \frac{Z_{ш}}{Z_0} \sqrt{10^{L/10} - 1}\right)^{-1}\right]^{-1} - 1$$

or

$$K_{пер} \approx 3 \frac{Z_{ш}}{Z_0} \sqrt{L} \text{ for } \frac{Z_{ш}}{Z_0} > 5 \text{ and } L \leqslant 1.0 \text{ decibels.}$$

The length of the shortcircuited loop $l = \Lambda_1/2\,(K_{пер} + 1)$, where Λ_1 is the wave length in the line on the lower frequency of the band. Thus, for $Z_0 = 50$ ohms, $Z_{ш} = 325$ Ohms on the edge frequencies of the band with overlap coefficient $K_{пер} = 6$, the introduced losses are 0.1 decibels. However, the technical band width when using the loop with the direct central conductor is limited by the minimum possible transverse dimensions of the conductor. A significant increase in width can be obtained when using the line in the form of the conical coil [25]. For the lines of this type the characteristic resistance on the order of 2,000 ohms is easily admissible. The data with respect to calculating the coaxial lines with spiral central conductor are presented in [11].

In order to exclude the necessity for using the high frequency chokes and in this way improve the technological nature of the structural design, it is possible to recommend, for example, series inclusion of the diodes in the nondirectional branching of the quarter-wave segments of the connected lines (Figure 3, a). With this method of constructing the switches, the necessity also disappears for using duct capacitors in the central conductors; the realization of the inputs of the control bias in the form of the separating capacitors C_p does not cause any special difficulties.

The increase in the decoupling of the disconnected channel can be obtained when using the single channel breakers based on the two-wire connected lines to construct the two-channel switches [26] (Figure 3, b). A characteristic feature of such switches is the fact that the input impedance of the disconnected channel is greater than the input impedance of the quarter-wave short circuited loop by about $\sqrt{2}$ times.

An interesting version of the switches with the shunting inclusion of the diodes at a quarter-wave distance from the branch point is the switch, the diagram of which is presented in Figure 3, c [27]. The wideband nature of the switches executed by the diagram in Figure 1, b is limited by the fact that the transmission channel is shunted by the quarter-wave loop with low $Z_{ш}$. In the switch the diagram for which is presented in Figure 3, c, the properties of the all transmitting links on the two-wire connected lines are used, the resistance of which can be varied within broad limits depending on the state of the switching diodes in the secondary lines. Here the resistance of the arm with the open diodes can be selected equal to Z_0 of the input and output lines, and they are with the closed diodes, larger than this resistance which insures good agreement in a wide frequency band.

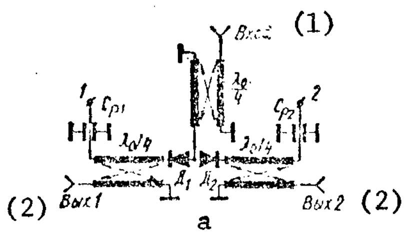
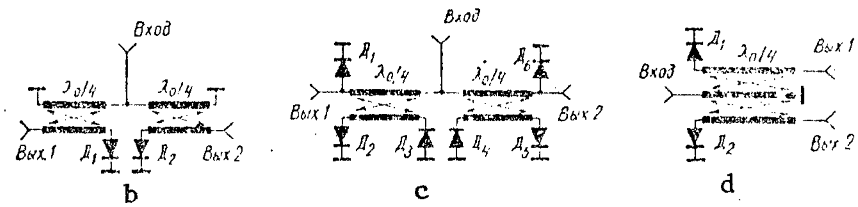


Figure 3. Basic diagrams of the microwave switches based on the two-wire and three-wire connected lines.



Key: (1) input
(2) output

The switches based on the multiple conducting connected lines are less investigated at the present time. The schematic of the two-channel switch based on the quarter-wave segment of the three-wire connected lines (Figure 3, d) is proposed in [28]. With an increase in the number of connected lines, which also means the number of commuted channels, these switches can compete with the matrix switches which contain usually the multichannel dividers and the set of phase shifters in the directional responders.

The standard values of the parameters of the investigated versions of the circuits for constructing the multichannel microwave switches are presented in Table 3.

Conclusion

The electrically controlled microwave switches based on the semiconductor diodes will permit a reduction in weight and size of the equipment, improvement of its speed, reduction of the expenditures of power on control and improvement of the reliability of the microwave systems.

Table 3

Standard Parameters of the Microwave Switches with p-i-n-diodes

№№ пп (1)	Особенности конструкции переключателя (2)	(3) Режим коммутации	(4) Параметры используемых диодов,	(5) Диапазон частот, ГГц	(6) КСВН	(7) Вносимые потери, дБ	(8) Развязка, дБ	(9) Уровень переключаемой мощности, Вт: средней (10)	импульсной (11)	(12) Источник
1	2	3	4	5	6	7	8	9	10	11
1	Последовательное включение диодов в МПЛ (13)	1←→4	(14) $C=0{,}06$ пФ $R=1{,}60$ Ом (15)	1,5÷2,1	1,16	0,33	29	3,75	—	[29]
2	Последовательное включение диодов в виде гибридной интегральной схемы (17)	1←→2	$C=0{,}04$ пФ $R=2{,}5$ Ом	8,5÷9,5	1,4	0,7	18	—	1	[S]
3	Последовательное включение диодов в виде монолитной интегральной схемы (18)	1←→2	$C=0{,}02$ пФ $C=0{,}005$ пФ $C=0{,}008$ пФ	8,5÷9,5 8,0÷9,0 8,0÷9,0	1,4 1,43 1,43	1,0 1,5÷2,0 1,5÷2,0	25 31 27	— 1 1	1 50 50	[8] [32] [32]
4	Последовательное включение диодов в МПЛ (19)	2←→4	—	2,0÷11	1,9	2,3	45	—	—	[21]
5	Последовательно-параллельное включение диодов в виде гибридной интегральной схемы (20)	1←→3 1←→5	— —	0,5÷18 0,5÷18	1,8 2,0	2,5 1,2÷3,7	40 70	— —	— —	[22] [22]
6	Параллельное включение диодов в коаксиальную линию (21)	1←→2	$C=1{,}0$ пФ $R=0{,}50$ Ом	1,0÷2,0	—	1,3	43	—	(16) 6 кВт	[39]
7 (22)	Параллельное включение диодов в виде гибридной интегральной схемы	1←→6 1←→24	$C=0.15$ пФ $C=0{,}15$ пФ	8,0÷16 8,0÷10	2,0 2,0	2,0÷3,5 7,0	20 40	— 20	2 кВт —	[21] [21]
8	Последовательно-параллельное включение диодов в ненаправленное разветвление двухпроводных связанных линий (23)	1←→2 1←→4	КА517В 2А516В КА517В 2А516В	октава (26) октава	1,6 1,8	1,3 2,0	22 35	1 1	— —	* *
9	То же, но с использованием одноканальных выключателей на двухпроводных связанных линиях (24)	1←→4	КА517В 2А516В	октава	1,8	2,0	20	1	—	*
10	На основе трехпроводных связанных ных линий (25)	1←→2	$C=0.4$ пФ $R=2.5$ Ом	$K_{пер}=3$ (27)	1,5	1,0	24÷16	—	—	*

* Results obtained by the authors.

[Key to table on following page

The most prospective from the point of view of expansion of the operating frequency band are the switches based on the single lines with the series parallel inclusion of the diodes. The potential possibilities of these circuits can be fully realized only with the application of the integrated circuit technology, and the hybrid method is especially suitable. The high levels of commuted power can be provided by switches with parallel inclusion of the diodes. The switches on the connected lines are characterized by great possibilities, but at the present time they are the least investigated.

The theory of optimal design of the narrow band microwave switches has been developed quite well, but sometimes the switches must be calculated for the maximum wide band nature, the maximum carrying capacity, and so on. In a number of cases this problem can be solved only with the use of a computer; therefore the problem of developing the algorithms for the analysis and optimization of the microwave switches based on semiconductor diodes is an urgent ones.

[Key to table on preceding page]

(1) Item No.
(2) Peculiarities of the switch design
(3) Commutation regime
(4) Parameters of the diodes used
(5) Frequency range, gigahertz
(6) Voltage standing wave ratio
(7) Introduced losses, decibels
(8) Decoupling, decibels
(9) Switchable power level, watts
(10) Mean
(11) Impulse
(12) Source
(13) Series inclusion of the diodes in the MPL
(14) pf = picofarads
(15) om = ohms
(16) kBt = kilowatts
(17) Series inclusion of the diodes in the form of the hybrid integrated circuit
(18) Series inclusion of the diodes in the form of the monolithic integrated circuit
(19) Series inclusion of the diodes in the MPL
(20) Series-parallel inclusion of the diodes in the form of the hybrid integrated circuit
(21) Parallel inclusion of the diodes in the coaxial line
(22) Parallel inclusion of the diodes in the form of the hybrid integrated circuit
(23) Series-parallel inclusion of the diodes in the nondirectional branching of the two-wire connected lines
(24) The same, but with use of the single-channel breakers based on the two-conductor connected lines
(25) On the basis of the three-wire connected lines.
(26) Octave
(27) Overlap coefficient

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BAND-PASS FILTERS WITH LINEAR PHASE CHARACTERISTICS

Moscow RADIOTEKHNIKA in Russian No 5, May 1977 pp 42-47

[Article by V. I. Vol'man and A. G. Sarkis'yants]

[Text] The majority of band-pass filters (PF) used in superhigh-frequency engineering belong to the class of minimum-phase circuits whose amplitude-frequency characteristic (AChKh) and phase-frequency characteristic (FChKh) are uniquely related. This property of the circuit imposes substantial limitations on the FChKh filters as a result of which there are considerable phase aberrations at the edges of their transmission bands.

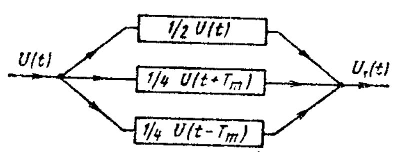

Figure 1

Let us examine a method of constructing PF free from the above mentioned drawback. Let us assume that the following signal is sent to the input of the circuit shown in Figure 1:

$$U(t)=\sum_{m=-\infty}^{\infty} b_m \cos\omega_m t. \qquad (1)$$

In writing (1), it was assumed that $\omega_m>\omega_0\ (m\geqslant 1)$ and $\omega_m<\omega_0\ (m<1)$, where ω_0 is a certain central frequency. The divider at the input of the system distributes the signal among three channels in the proportion shown in Figure 1, i.e., the amplitude of the signal at the input of the upper channel is equal to 1/2 U(t), and at the inputs of the middle and lower channels it is 1/4 U(t).

We shall limit ourselves to the examination of dispersionless systems. Then at the output of the upper channel we shall obtain (Figure 1)

$$U_{\text{в}}(t)=\frac{1}{2}\sum_{m=-\infty}^{\infty} b_m \cos\omega_m\left(t-\frac{l}{c}\right),$$

middle channel

$$U_{\text{c}}(t)=\frac{1}{4}\sum_{m=-\infty}^{\infty} b_m \cos\omega_m\left(t-\frac{l}{c}+\frac{2\pi}{\omega_0}\right),$$

lower channel

$$U_{\text{н}}(t)=\frac{1}{4}\sum_{m=-\infty}^{\infty} b_m \cos\omega_m\left(t-\frac{l}{c}-\frac{2\pi}{\omega_0}\right)$$

(here, l is the length of the channel; c is the velocity of light), i.e., the signals in the middle and lower channels receive an additional phase shift of $\pm 2\pi$ on a frequency of ω_0 and $\pm 2\pi\frac{\omega_m}{\omega_0}$ on other frequencies. Summing the signals at the output of the system by means of a summator with the same parameters as the divider at the input, we obtain

$$U_1(t)=U_{\text{в}}(t)+U_{\text{c}}(t)+U_{\text{н}}(t)=$$
$$=\sum_{m=-\infty}^{\infty} b_m \cos^2\left(\pi\frac{\omega_m}{\omega_0}\right)\cos\omega_m\left(t-\frac{l}{c}\right). \quad (2)$$

It follows from (2) that this circuit has definite selective properties. For example, on frequencies of $\omega_m=\frac{2q-1}{2}\omega_0$ at q = 1, 2, 3... $\cos^2\pi\frac{\omega_m}{\omega_0}=0$, i.e., a signal with these frequencies reflects completely from the inlet. If we pass a signal through a circuit consisting of R such circuits, then we shall have the following at its output:

$$U_R(t)=\sum_{m=-\infty}^{\infty} b_m \cos^{2R}\left(\pi\frac{\omega_m}{\omega_0}\right)\cos\omega_m\left(t-\frac{Rl}{c}\right).$$

Consequently, the complex transmission factor of a circuit consisting of R such sections is equal to

$$K_R(\omega)=\cos^{2R}\left(\pi\frac{\omega}{\omega_0}\right)e^{-i\omega t_1}$$

[where t_1 = Rl/c), i.e., individual sections and the entire circuit have linear FChKh.

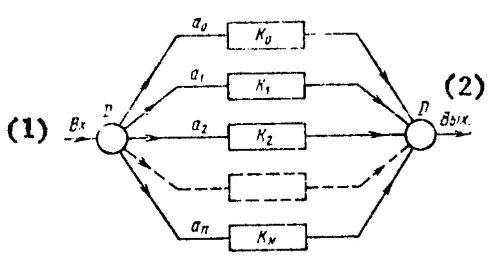

Figure 2
Key: 1. Input
2. Output

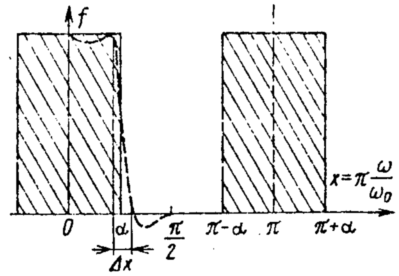

Figure 3.

Let us determine the transmission factor of the circuit in Figure 2 which has identical dividers at the input and output. The amplitudes of the signals in the arms of the dividers are a_0, a_1, a_2, a_3, ..., a_N. Let the first channel have transmission coefficient $K_0\ (\omega) = a_0$, the circuit of Figure 1 with a transmission factor $K_1(\omega) = a_1 \cos^2\left(\pi \frac{\omega}{\omega_0}\right) e^{-i\omega t_1}$ is connected to the second channel, the third channel has two cells connected in series with overall transmission factor $K_2(\omega) = a_2 \cos^4\left(\pi \frac{\omega}{\omega_0}\right) e^{-i\omega t_1}$, etc. The total transmission factor of the system is equal to

$$K(\omega) = e^{-i\omega t_1} \sum_{n=0}^{N} a_n z^n, \tag{3}$$

where $z = \cos^2\left(\pi \frac{\omega}{\omega_0}\right) = \cos^2 x$. The transmission factor (3) is an even function with period $\Delta\omega = (n-1)\omega_0$.

The AChKh of an ideal PF is shown in Figure 3, where dimensionless quantity $x = \pi \frac{\omega}{\omega_0}$ is plotted along the horizontal axis. Expanding f (x) in the Fourier series, we have

$$f(x) = \frac{b_0}{2} + \sum_{k=1}^{\infty} b_k \cos 2kx = \begin{cases} 1 & 0 \leqslant x \leqslant \alpha, \\ 0 & \alpha \leqslant x \leqslant \frac{\pi}{2}, \end{cases} \tag{4}$$

where $b_0 = \int_0^{\alpha} f(x)\,dx = \alpha;\ b_k = \frac{4}{\pi}\int_0^{\alpha} \cos 2kx\,dx = \frac{2\alpha}{\pi}\,\frac{\sin 2k\alpha}{k\alpha};\ \alpha = \pi\frac{\omega_{rp}}{\omega_0}$ is the normalized boundary of the transmission band.

Equating the right parts of expressions (3) and (4), we obtain the equality

$$\frac{\alpha}{2} + \sum_{k=1}^{\infty} b_k \cos 2kx = \sum_{n=0}^{N} a_n \cos^{2n} x. \tag{5}$$

As one would expect, the realization of the AChKh with ideal slopes is possible only at $N \to \infty$. At finite values of N, expression (5) assumes the following form:

$$\frac{a}{2} + \frac{2a}{\pi}\sum_{k=1}^{N}\frac{\sin 2ka}{ka}\cos 2kx = \sum_{n=0}^{N} a_n \cos^{2n} x. \qquad (6)$$

The left part of equation (6) has a finite sum corresponding tc the Fourier series for a square pulse, i.e., this expression at finite values of N describes the pulse shape at the output of an ideal PF with a boundary frequency of the transmission band equal to Nw_0. Then the buildup time of the pulse of the synthesized filter will be equivalent to the width of the transitional area Δx between the transmission band and the attenuation band. Consequently, $\Delta\omega/\omega_0 \approx 1/N$. This analogy of the shape of the AChKh of

the filter with the shape of the signal at the output of an ideal PF makes it possible to make use of the results of the calculations from [1] for determining the AChKh. Let us represent cos 2kx in (6) in the form of the following series

$$\cos 2kx = \sum_{p=0}^{k} C_p^k \cos^{2p} x. \qquad (7)$$

Having designated x = arccos y, we have

$$\cos(2k \arccos y) = \sum_{p=0}^{k} C_p^k y^{2p}. \qquad (8)$$

The left part of expression (8) is the Chebyshev polynomial of the first kind of even order, therefore, the coefficients in the right part are the coefficients of this polynomial [2]:

$$C_p^k = \frac{(-1)^{k-p} 2k\,(k+p-1)!\,2^{2p-1}}{(2p)!\,(k-p)!}.$$

With consideration for (7) expression (6) assumes the following form:

$$\frac{a}{2} + \frac{2a}{\pi}\sum_{k=1}^{N}\frac{\sin 2ka}{ka}\sum_{p=0}^{k} C_p^k \cos^{2p} x = \sum_{n=0}^{N} a_n \cos^{2n} x. \qquad (9)$$

Having changed the summation order in the left part of expression (9), we shall obtain

$$\sum_{p=0}^{N}\left\{\delta_p \frac{a}{2} + \frac{4a}{\pi}\sum_{k=p}^{N} C_p^k \frac{\sin 2ka}{2ka}\right\}\cos^{2p} x = \sum_{n=0}^{N} a_n \cos^{2n} x, \qquad (9')$$

where $\delta_p = \begin{cases} 1 \text{ at } p = 0, \\ 0 \text{ at } p \neq 0. \end{cases}$

From (9') we have

$$a_0 = \frac{\alpha}{2} + \frac{4\alpha}{\pi} \sum_{k=1}^{N} (-1)^k \frac{\sin 2k\alpha}{2k\alpha}, \tag{10}$$

$$a_n = \frac{4\alpha}{\pi} \sum_{k=n}^{N} \frac{(-1)^{k-n} 2k\,(k+n-1)!\, 2^{2n-1}}{(2n)!\,(k-n)!} \; \frac{\sin 2k\alpha}{2k\alpha}. \tag{11}$$

Table 1

N \ a_n	a_0	a_1	a_2	a_3	a_4
2	—0,169	0,34	0,775	—	—
3	0,015	—2,968	9,6	—5,881	—
4	—0,087	0,307	—6,776	20,321	—13,1

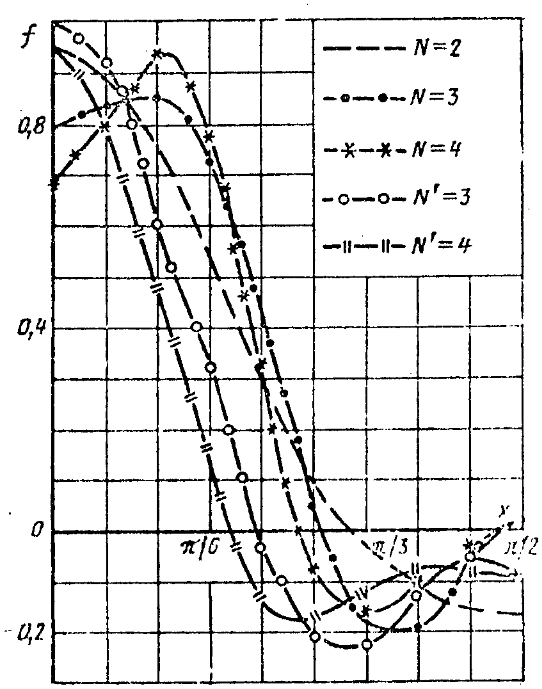

Figure 4

The values of scaling factors a_n for $N = 2 \div 4$ at $\alpha = 0.22\pi$ are shown in Table 1 and the AChKh of the filters are given in Figure 4. As can be seen, the values of factors a_n differ substantially from one another: for example, $N = 4$ $a_o = 0.087$, $a_3 = 20.321$. Therefore, in the PF channels it is necessary to use transformers in the form of lines with reduced or increased wave impedance, which complicates the design. This can be avoided if we require that factors a_n should satisfy the relation

$$\sum_{n=0}^{N_1} |a_n| = 1.$$

Let us rewrite expression (3), assuming that $y = \cos^2 \frac{\pi\omega}{\omega_0}$:

$$K(y) = \sum_{n=0}^{N_1} a_n y^n,$$

where $0 \leq y \leq 1$. Consequently, for synthesizing a filter, it is possible to use one of the methods of nonlinear programming [3].

It can be seen from Figure 4 that, when f(x) is approximated by the Fourier series, there are considerable oscillations of the AChKh in the transmission band of the PF which are caused by the so-called Gibbs phenomenon. They can be eliminated by using Feyer's method of arithmetic mean or the method of smoothing by means of σ-factors [4]. The arithmetic mean method removes Gibbs' oscillations but has a drawback because it gives a very slow approximation to the asymptotic value. This results in a considerable increase of losses in the transmission band of the filter and in considerable "lagging" of the transitional region Δx.

When using the method of σ-factors, the transitional region narrows considerably and losses in the transmission band of the PF decrease, but insignificant oscillations of the AChKh remain. Applying the method of σ-factors, we write

$$f_N(x) = \sigma_0 a_0 + \sigma_1 a_1 \cos^2 x + \sigma_2 a_2 \cos^4 x + \ldots + \sigma_N a_N \cos^{2N} x,$$

where $\sigma_n = \frac{2}{N} \cdot \frac{\sin \frac{n\pi}{N}}{\frac{n\pi}{N}}$ at $N > 2$.

Table 2 shows the values of factors a_n with consideration for their correction by means of σ-factors, and Figure 4 shown the AChKh of the filters after correction.

Table 2

N \ a_n	a_0	a_1	a_2	a_3	a_4
3	0,015	—1,637	2,647	0	—
4	—0,087	0,138	—2,158	3,048	0

As can be seen, the differences of factors a_n decrease after correction. The positive fact is the reduction of the number of terms in the expansion of function f(x), i.e., a decrease in the number of channels in the dividers.

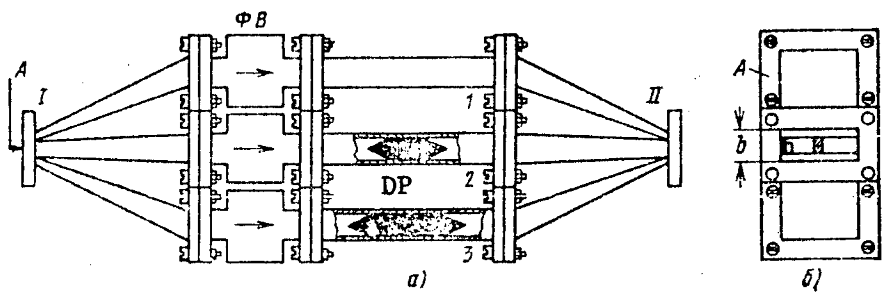

Figure 5

Figure 5 shows the design of a waveguide variant of a cell of a filter with the AChKh of the $\cos^2\left(\pi \frac{\omega}{\omega_0}\right)$ -type. This cell is the main component of the filter. The dividers are smooth waveguide bifurcations of a standard-cross section waveguide (23 x 10) mm^2 whose narrow wall is divided by metal partitions into parts b/4, b/2, and b/4 (see Figure 5) connected to three waveguides of the same cross section. This makes it possible to obtain the required amplitudes of signals in each of the channels of the cells. The phase inverters are constructed of dielectric plates (DP). In order to obtain the necessary phase ratios, let us place in arm 2, to which a signal with an amplitude of 1/2U(t) branches off, a dielectric plate making it possible at frequency w_o to obtain a phase shift of 2π between signals in arms 1 and 2 and a phase shift of 4π between signals in arms 1 and 3. Then, the phase shift in arm 1 in relation to arm 2 will be equal to $+2\pi$, and in arm 3 -- 2π. At the output of the system, there forms a signal equal to

$$U_1(t) = \sum_{m=-\infty}^{\infty} b_m \cos^2\left(\frac{\omega_m}{\omega_0}\varphi_m\right)\cos\omega_m\left(t - \frac{l}{c}\right); \qquad (12)$$

where $\varphi_m = \frac{\pi(\Lambda_m - \lambda_m/\beta_m)}{\Lambda_m \lambda_m/\beta_m} l_д$; Λ_m is the wave length in the waveguide on frequency w_m; λ_m is the wave length in a free space on frequency w_m; β_m is the moderation ratio [5]; l is the length of the dielectric plate.

Ferrite isolators (FV) are used because of the necessity of eliminating undesirable resonances occurring in the cell. Since a definite part of energy on frequencies different from f_0 reflects from the outlet of the divider II, then, passing for the second time through channels 1-3, the signals will receive additional phase shifts, and they will arrive at the outlet of divider I with some arbitrary phase. Some of the energy will go to the inlet of divider I, and some of it will be reflected and will reenter channels 1-3, etc. As a result of this, there will be dead spots in the AChKh of the cell caused by resonances, which will make it impossible to realize the required AChKh.

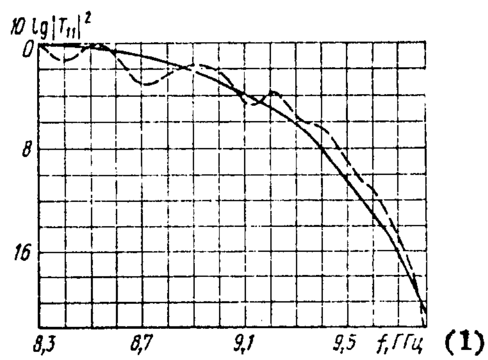

Figure 6.

Key: 1. GHz

Figure 6 shows experimental AChKh of the cell in Figure 5 and the AChKh calculated by formula (12).

The design of the cell shown in Figure 5 can be simplified substantially by using the same ferrite inserts as phase inverters and isolators. For example, these inserts can be made of different lengths, which will make it possible to obtain the required phase shifts for direct waves. There are no strict requirements for return losses, because it is sufficient if each of the isolators yields a return loss on the order of 8-10 dB.

In realizing the filters shown in Figure 2, the series of division coefficients a_n calculated by (10) and (11) can be negative. In order to fulfill this requirement, it is necessary to create in some of the channels a frequency-independent phase shift equal to π . In the waveguide variant of the filter, the role of such a phase inverter can be played by a 180 degree waveguide structure.

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REALIZATION OF DISCRETE-ANALOG RECURSIVE FILTERS

Moscow RADIOTEKHNIKA In Russian No 5, May 1977 pp 48-51

[Article by A. Yu. Dzevanovskaya and I. A. Tsikin]

[Text] Methods based on sampling of input signals are used more and more widely for the filtration of signals. Interest in discrete filters is determined by a number of advantages, such as: a high stability of their characteristics; the possibility of working on ultralow frequencies; the possibility of the realization of comb filters using the property of spectrum "multiplication" during sampling; simplicity of retuning; the possibility of microminiaturization, etc.

Discrete filters are realized, as a rule, in a digital form [1]. However, digital filters have a number of drawbacks. One of them is the necessity of using analog-digital converters, digital computers, or relatively complex specialized devices; the presence of noises connected with level quantization and rounding during computations; a relatively slow action when working on a real time scale.

Discrete-analog filters [2] are free from the above-mentioned drawbacks to a considerable degree. When designing frequency-selective circuits it is expedient to realize them on the recursive principle [1,3].

The main problems occurring during the development of discrete-analog recursive filters (DARF) and digital filters are restoration of the output signal in a continuous form and evaluation of permissible inaccuracies in establishing the weight coefficients of the filter.

It is evident that the accuracy of accomplishing the weight coefficients, as well as the stability of the timing oscillator and the type of the block diagram of the filter determine the stability and accuracy of the DARF characteristics [3]. Taking into consideration that filters of high orders can be designed in the form of parallel or cascade connection of sections of the first and second orders, let us examine the effect of errors caused by inaccurate values of the weight coefficients on the type of the characteristic of a DARF of the second order.

As is known, the transfer function of such a filter H(z) in the z-region has the following form:

$$H(z)=\left[1-2\exp\left(-\frac{\Delta\omega T}{2}\right)\cos\omega_0 T z^{-1}+\exp(-\Delta\omega T)z^{-2}\right]^{-1}=$$
$$=\frac{1}{1+b_1 z^{-1}+b_2 z^{-2}}, \tag{1}$$

where ω_0 and $\Delta\omega$ are the resonance frequency and band of the analog filter; T is the sampling time.

From (1) it is easy to obtain an expression for the values of relative errors with respect to resonance frequency $(\delta\omega_0/\omega_0)$ and with respect to the band $(\delta\Delta\omega/\Delta\omega)$. If errors Δb_1 and Δb_2 in the determination of weight coefficients b_1 and b_2 are small, then

$$\left.\begin{aligned}\frac{\delta\omega_0}{\omega_0}&=\frac{1}{2\omega_0 T\,\mathrm{tg}\,\omega_0 T}\left(\frac{\Delta b_2}{b_2}+2\frac{\Delta b_1}{b_1}\right),\\ \frac{\delta\Delta\omega}{\Delta\omega}&=\frac{1}{\Delta\omega T}\frac{\Delta b_2}{b_2}.\end{aligned}\right\} \tag{2}$$

It follows from (2) that the relative error in respect to resonance frequency is determined both by inaccuracy in the presentation of weight coefficients, as well as the value of $\omega_0 T$ which, if the systematic error of discrete analog processing [2] equals to zero, assumes values close to $(2\alpha+1)\frac{\pi}{2}$, where α designates whole numbers. With a very low accuracy in the determination of weight coefficients, the frequency error is sufficiently small. For example, at $\Delta b_1/b_1=\Delta b_2/b_2=10\%$ we have $\delta\omega_0/\omega_0\leqslant 2\%$.

The relative error with respect to band (2) depends on $\Delta b_2/b_2$ and $\Delta\omega T$ and at fixed $\Delta b_2/b_2$ it increases with the sampling frequency $\omega_д=2\pi/T$.

Thus, at $\Delta b_2/b_2=10\%$ $\delta\Delta\omega/\Delta\omega=3{,}2\%$ at $\omega_д=2\Delta\omega$ and

$\delta\Delta\omega/\Delta\omega=8\%$ at $\omega_д=5\Delta\omega$.

A considerable decrease of $\Delta\omega T$ at fixed $\Delta b_2/b_2$ is also inexpedient because it may violate the stability condition of DARF if the poles H(z) are shifted beyond limits of the unit circle [1]. Taking into consideration that the poles in the z-plane are defined by polar coordinates

$$r=\sqrt{b_2},\quad \theta=\omega_0 T=\pm\arccos\frac{b_1}{2\sqrt{b_2}},$$

we can readily obtain the stability condition of the filter:

$$\Delta\omega T>2\ln\left(1+0{,}5\frac{\Delta b_2}{b_2}\right). \tag{3}$$

If it is necessary to ensure low $\delta\Delta\omega/\Delta\omega$, condition (3) is almost always fulfilled, but the characteristics of DARF are very sensitive to the values of $\Delta b_2/b_2$ and $\Delta\omega T$.

Since in real DARF the attainable accuracy of setting up weight coefficients $\Delta b_1/b_1$ and $\Delta b_2/b_2$ constitutes units of percentages, the error $\delta\Delta\omega/\Delta\omega$ can be decreased only when the sampling frequency is lowered to values of $\omega_д \approx 2\Delta\omega_c$, where $\Delta\omega_c$ is the band of the input signal. The latter, in turn complicates the regeneration of the analog signal at the output of the filter.

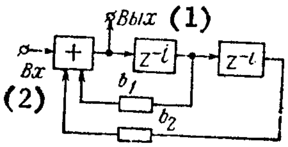

Figure 1

Key: 1. Output
2. Input

The DARF circuit makes it possible to remove the contradictions in the requirement imposed on the simple regeneration circuit and low permissible accuracy of setting b_2 (Figure 1). Here, the sampling frequency of the input signal $\omega_{дс}$ is i times greater than the sampling frequency of the pulse response of the corresponding analog filter $\omega_{дф}$. In this case, the necessary accuracy of setting the weight coefficients is, evidently, determined by frequency $\omega_{дф}$, and the parameters of the regeneration circuit -- by frequency $\omega_{дс}$.

In accordance with the condition that the systematic error of discrete analog processing should be equal to zero [2], the following relation must be fulfilled for the DARF under consideration:

$$\begin{cases} \dfrac{\omega_0}{\omega_{дс}} = \dfrac{2n_c+1}{4} \\ \dfrac{\omega_0}{\omega_{дф}} = \dfrac{2n_ф+1}{4} \end{cases} \quad \left.\begin{matrix} n_c = \\ n_ф = \end{matrix}\right\} 0, 1, \ldots, \left[\frac{\omega_0}{\Delta\omega_c} + \frac{1}{2}\right].$$

In this case, it is necessary to select $n_ф > n_c$ in such a way that

$$i = \frac{\omega_{дс}}{\omega_{дф}} = \frac{2n_ф+1}{2n_c+1} \qquad (4)$$

would be a whole number.

It is evident that for the circuit of Figure 1 i is determined by the parameters of the regeneration circuit, and the value of $\omega_{дф}$ is selected close to the limit value of $\omega_{дф} \approx 2\Delta\omega_c$ in order to ensure a minimal sensitivity of the filter to errors in weight coefficients (2).

The DARF discussed above was a DARF of the second order of the polynomial kind (1). In the presence of zeros in H(z), inaccuracy in their representation also influences the parameters of the filter. For example, in case of a real zero,

$$H(z) = (1 - a_1 z^{-1}) / (1 + b_1 z^{-1} + b_2 z^{-2}). \qquad (5)$$

The AChKh of such a filter is defined as:

$$|H(\omega)| = g(\omega)\left(1 + a_1^2 - 2a_1 \cos \omega T\right)^{1/2},$$

where

$$g(\omega) = \{[1 + r^2 - 2r \cos(\omega - \omega_0) T][1 + r^2 - 2r \cos(\omega + \omega_0) T]\}^{-1/2}.$$

The change of $\Delta |H(\omega)|$ with the deviation of the weight coefficient $\Delta a1$ is equal to

$$\Delta |H(\omega)| = \frac{a_1 - \cos \omega T}{\sqrt{1 + a_1^2 - 2a_1 \cos \omega T}} g(\omega) \Delta a_1.$$

Sections of type (5) are used widely in realizing filters of high orders, Lerner filters, etc. For them, $a_1 = r \cos \omega_0 T$. It is possible to have filters with $a_1 = 1$ and $a_1 = \cos \omega_0 T$ [1]. It can be easily ascertained that for any ωT and $|a_1| \leqslant 1$, the value of $\Delta |H(\omega)|$ does not exceed $\Delta a1/a_1$.

In designing rejection filters, equalizers of phase characteristics, and filters using fractional approximation, H(z) has conjugate complex zeros:

$$H(z) = \frac{a_0 + a_1 z^{-1} + a_2 z^{-2}}{1 + b_1 z^{-1} + b_2 z^{-2}}.$$

For these filters, $a_0 = a_2 = 1$; the AChKh of filters with conjugate complex zeros has the form

$$|H(\omega)| = (a_0^2 + a_1^2 + a_2^2 + 2a_0 a_1 \cos \omega T +$$
$$+ 2a_0 a_2 \cos 2\omega T + 2a_1 a_2 \cos \omega T)^{1/2} g(\omega).$$

The effect of the inaccuracy of weight coefficients a_0, a_1 and a_2 on the kind of the AChKh is equivalent, therefore we shall examine the changes of $\Delta |H(\omega)|$ at $a_0 = a_2 = 1$ and a_1 = var. In this case

$$\Delta |H(\omega)| = \frac{a_1 + 2 \cos \omega T}{\sqrt{2 + a_1^2 + 4a_1 \cos \omega T + 2 \cos 2\omega T}} g(\omega) \Delta a_1.$$

For the cases of $|a_1| \leqslant 1$, which are of practical interest, the changes in the AChKh do not exceed $\Delta a_1/a_1$ over the entire range of possible values of ωT.

As has been mentioned above, the inaccuracy of weight coefficients $(\Delta a_1/a_1)$ in discrete-analog systems does not exceed a few percent. Consequently, in constructing a DARF, deviation of AChKh from the prescribed characteristic is determined, chiefly, by the inaccuracy in the realization of weight coefficients of the denominator which determine the position of the poles of characteristic H(z).

The realization of the DARF examined above does not present any difficulties [3-4]. For example, Figure 2 shows a diagram of a filter of the second order of the polynomial kind with large-capacity memory elements [4] constructed on microcircuits of the 1YT401 and K1KT901-type (f_{01}, f_{02}, f_1, f_2, f_3 are cadence sequences controlling the work of the filter).

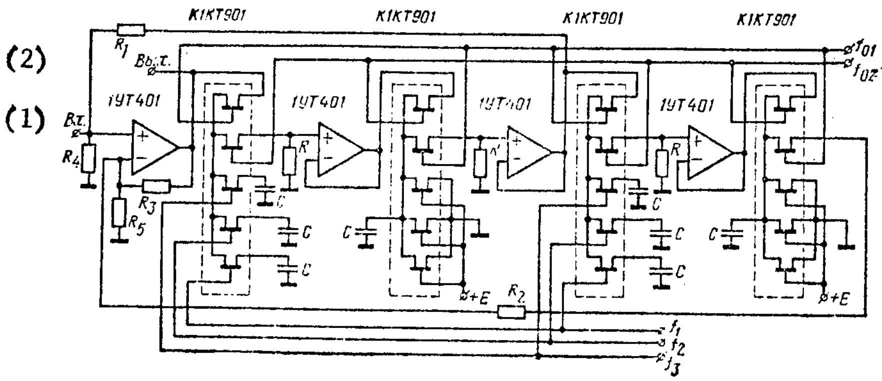

Figure 2

Key: 1. Input
2. Output

Qualitative checking of the possibilities of stable operation of a DARF with prescribed parameters and practical realizable accuracy of setting weight coefficients within the limits of 1-2 percent was done on a model of a DARF of the fourth order composed of sections analogous to those shown in Figure 2; the signal quantification frequency was 10 kHz, and the quantification frequency of the pulse reaction of the filter was three times smaller (i = 3). Figure 3 shows the characteristics of such a filter for three values of the frequency band $\Delta\omega_1 = 570$ Hz (curve 1); $\Delta\omega_2 = 430$ Hz (curve 2) and $\Delta\omega_3 = 115$ Hz (curve 3). The value of the minimum band correcponding to steady operation is well in agreement with the results of studies on the stability of the sections of the second order discussed above.

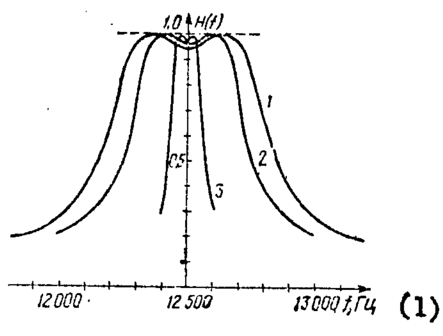

Figure 3

Key: 1. Hertz

Thus, the DARF with $\omega_{\text{дс}} = i\omega_{\text{дф}}$ discussed above removes the main difficulties connected with its realization, satisfies the requirement for microminiaturization and makes it possible to use such filters widely for frequency selection.

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SELECTION OF CELESTIAL BODIES FOR AZIMUTH DETERMINATION

Leningrad IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY PRIBOROSTROYENIYE in Russian Vol 20 No 4, 1977 pp 75-79

[Article by M. A. Sergeyev, Leningrad Institute of Precise Mechanics and Optics]

Abstract: The article describes a method for ascertaining the mean square error in determining the azimuth of celestial bodies in dependence on the errors in position latitude and longitude. A nomogram is constructed for the equal errors on the plane representing the equatorial coordinates of the celestial bodies. It is shown that a lesser error is obtained with tie-in to celestial bodies situated in the northern part of the celestial hemisphere.

[Text] Special navigational systems are required for an aeromagnetic survey of the earth, aerial reconnaissance of minerals and field tests of pilotage instruments and in other investigations. Such systems are usually not used in the entire trajectory segment of a moving object. In addition, navigational information is frequently fed discretely at specific time intervals or for specific trajectory intervals. The navigational systems for these investigations are not necessarily all-weather. However, extremely rigorous requirements are placed on their accuracy [1].

In the navigational system developed at the Leningrad Institute of Precise Mechanics and Optics for vector aeromagnetic investigations the angular positions of the aircraft relative to the coordinate system oriented geographically are corrected (are determined) by means of a tie-in to one or two celestial bodies with known equatorial coordinates: δ -- declination and $t_i = t_{Gr} - \lambda_i + \alpha$ -- the hour angle [2, 3]. In this procedure the geographical latitude φ_i and longitude λ_i of position of the moving object in each i-th measurement are computed from the slant range and the bearing determined by the NNGRS (near navigation ground radio station) and also on the basis of flight altitude above sea level [4].

The navigational system includes two astrosights whose optical axes are automatically held in the directions to the corresponding celestial bodies. The azimuth A_i of a celestial body is computed using the formula [5]

$$\operatorname{ctg} A_i = \cos\varphi_i \operatorname{tg}\delta \operatorname{cosec} t_i - \sin\varphi_i \operatorname{ctg} t_i. \tag{1}$$

After having the azimuth A_i of the celestial body and its course angle Q_i, it is possible to compute the course K_i of the flightcraft (FC). The course angle q_i is determined from the azimuth ring of the astrosight and then is corrected by the value of the correction Δq_i caused by the inclination of the stabilized astrosight platform. Then $Q_i = q_i + \Delta q_i$.

The parameters δ -- declination, α -- right ascension of the celestial body and t_{Gr} -- Greenwich time, entering into formula (1) are known with an extremely high accuracy. A considerable error in computing the azimuth of a celestial body is introduced by the errors in determining the position coordinates of the FC, latitude $\Delta\varphi$ and longitude $\Delta\lambda$. If both sides of equation (1) are expanded into a Taylor series in powers of ΔA, $\Delta\varphi$ and $\Delta\lambda$ relative to the true values A, φ and λ and if one neglects values of the second and higher orders of magnitude, we can obtain the error equation:

$$\Delta A = -\sin^2 A\left(\frac{\partial \operatorname{ctg} A}{\partial\varphi}\Delta\varphi + \frac{\partial \operatorname{ctg} A}{\partial\lambda}\Delta\lambda\right). \tag{2}$$

The random values $\Delta\varphi$ and $\Delta\lambda$, characterized by the mean square errors σ_φ and σ_λ, cannot be related in a correlation on a practical basis and therefore the mean square error σ_A in computing the azimuth, in accordance with equations (1) and (2), is determined by the expression [1]:

$$\sigma_A = \sqrt{n_1^2\sigma_\varphi^2 + n_2^2\sigma_\lambda^2}, \tag{3}$$

where

$$n_1 = \frac{\sin\varphi \operatorname{tg}\delta \operatorname{cosec} t + \cos\varphi \operatorname{ctg} t}{1 + (\cos\varphi \operatorname{tg}\delta \operatorname{cosec} t - \sin\varphi \operatorname{ctg} t)^2}; \tag{4}$$

$$n_2 = \frac{\cos\varphi \operatorname{tg}\delta \cos t - \sin\varphi}{\sin^2 t + (\cos\varphi \operatorname{tg}\delta - \sin\varphi \cos t)^2}. \tag{5}$$

The reduction factors n_1 and n_2 in formula (3) for the considered position latitude φ are dependent on the equatorial coordinates of the celestial bodies (δ, t).

Now we will first examine how the special error in computing azimuth $\sigma_A(\varphi)$, caused by the error in measuring local latitude, changes:

$$\sigma_A(\varphi) = n_1\sigma_\varphi. \tag{6}$$

We will determine the equatorial coordinates of the celestial bodies in the tie-in to which the coefficient $n_1 = 0$. It follows from (4) that

$$\cos t = -\operatorname{tg}\varphi \operatorname{tg}\delta. \tag{7}$$

The derived expression indicates that the celestial bodies are situated in the plane of the horizon. In actuality, having in the polar triangle the altitude of the celestial body H = 0, we obtain expression (7) [5]. It follows from this expression that for the considered local latitude the declinations should fall in an interval satisfying the condition

$$|\operatorname{tg}\delta| \leqslant \left|\frac{1}{\operatorname{tg}\varphi}\right|; \quad |\delta| \leqslant |90^\circ - \varphi|. \tag{8}$$

For clarity in the exposition, in the coordinate system (δ, t) (see Fig. 1) we constructed the HL (horizon line) curve for the local latitude φ = 60° and $|\delta| \leqslant 30°$. The celestial bodies whose equatorial coordinates are situated on the constructed curve have a reduction factor $n_1 = 0$ and a special error from the error in determining local latitude $\sigma_A(\varphi) = 0$.

We will construct the dependences for $n_1 \neq 0$. Reducing expression (4) to the common denominator, we obtain

$$\begin{aligned}(n_1 \cos^2\varphi \operatorname{cosec}^2 t)\operatorname{tg}^2\delta - \operatorname{cosec} t\,(n_1 \sin 2\varphi \operatorname{ctg} t + \sin\varphi)\operatorname{tg}\delta - \\ - (\cos\varphi - n_1 \sin^2\varphi \operatorname{ctg} t)\operatorname{ctg} t + n_1 = 0.\end{aligned} \tag{9}$$

The solution of this quadratic equation after some transformations has the form

$$\operatorname{tg}_{1,2}\delta = \frac{(2n_1 \cos\varphi \operatorname{ctg} t + 1)\sin\varphi \pm \sqrt{4n_1(\operatorname{ctg} t - n_1\cos\varphi)\cos\varphi + \sin^2\varphi}}{2n_1\cos^2\varphi}\sin t. \tag{10}$$

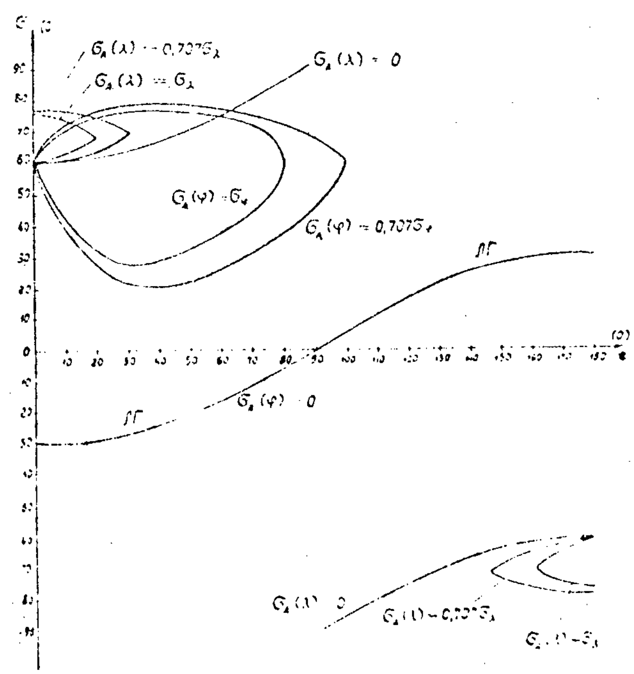

Fig. 1. Nomogram of equal special mean square errors in determining azimuth for a local latitude φ = 60°.

We will first assume that t = 0. Then it follows from the solution of (10) that

$$\mathrm{tg}_{12}\,\delta = \mathrm{tg}\,\varphi; \quad \delta = \varphi.$$

We establish from the derived equation that with any value $n_1 \neq 0$ the sought-for curves pass through a point with the coordinates $t = 0$, $\delta = \varphi$. For convenience in constructing the curves we determine the positions of the points on the plane t, δ, for which $\mathrm{tg}\,\delta$ (see formula (10)) has one value. For this we equate the radicand to zero. As a result we obtain

$$\mathrm{ctg}\,t_0 = \frac{4n_1^2\cos^2\varphi - \sin^2\varphi}{4n_1\cos^2\varphi}.$$

Substituting t_0 into formula (10), we obtain the sought-for δ_0 value:

$$\mathrm{tg}\,\delta_0 = \frac{(2n_1\cos\varphi\cos t_0 + \sin t_0)\sin\varphi}{2n_1\cos^2\varphi}.$$

Then it is necessary to compute for each coordinate t lying in the interval $0 < t < t_0$ two δ values using formula (10). Figure 1 shows two curves for the local latitude $\varphi = 60°$ with values of the coefficients $n_1 = 0.707\sigma_\varphi$ and $n_1 = 1$, denoted $\sigma_A(\varphi) = 0.707\sigma_\varphi$ and $\sigma_A(\varphi) = \sigma_\varphi$ respectively. With tie-in to celestial bodies situated on the constructed curves, the special errors in the computed value of azimuth of the celestial body caused by the error in determining local latitude are determined by the expressions

$$\sigma_A(\varphi) = 0{,}707\sigma_\varphi; \quad \sigma_A(\varphi) = \sigma_\varphi.$$

respectively.

With tie-in to celestial bodies with coordinates situated outside the constructed regions, the special errors in computing azimuth will be less:

$$\sigma_A(\varphi) < 0{,}707\sigma_\varphi; \quad \sigma_A(\varphi) < \sigma_\varphi.$$

Similarly, in the coordinate system (t, δ) we construct curves for fixed values of the reduction factor n_2. Assuming in equation (5) that $n_2 = 0$, we obtain

$$\cos t = \mathrm{tg}\,\varphi\,\mathrm{ctg}\,\delta. \tag{11}$$

The cited expression (11) is satisfied for a polar triangle with a right parallactic angle. Dependence (11) for the considered local latitude φ imposes a limitation on the declination angles. Since $|\cos t| \leqslant 1$, then

$$|\mathrm{tg}\,\varphi\,\mathrm{ctg}\,\delta| \leqslant 1.$$

Using this condition we establish the interval of possible values of declinations of celestial bodies $|90°|>|\delta|\geqslant|\varphi|$, for which $n_2 = 0$. In the figure in the indicated intervals for a latitude $\varphi = 60°$, using formula (11) we constructed two curves designated $\sigma_A(\lambda) = 0$. With a tie-in to the celestial bodies whose coordinates are situated on the constructed curves, the error in determining local longitude causes virtually no error in determining azimuth, that is, the special error $\sigma_A(\lambda) = 0$.

We will construct curves on the plane (t, δ) for the values $n_2 \neq 0$. Reducing expression (5) to a common denominator, we obtain

$$n_2 \cos^2\varphi \operatorname{tg}^2\delta - (n_2 \sin 2\varphi + \cos\varphi)\cos t \operatorname{tg}\delta + \sin\varphi + \\ + n_2(\sin^2 t + \cos^2 t \sin^2\varphi) = 0. \tag{12}$$

The solution of the quadratic equation (12) after some transformations has the form

$$\operatorname{tg}_{12}\delta = \frac{(2n_2 \sin\varphi + 1)\cos t \pm \sqrt{[4n_2(n_2 + \sin\varphi) + 1]\cos^2 t - 4n_2(n_2 + \sin\varphi)}}{2n_2\cos\varphi}. \tag{13}$$

First we will determine the declinations for the hour angles $t = 0°$ and $t = 180°$. As a result we accordingly obtain

$$\operatorname{tg}_1\delta = \operatorname{tg}\varphi + \frac{1}{n_2\cos\varphi}; \quad \operatorname{tg}_2\delta = \operatorname{tg}\varphi; \tag{14}$$

$$\operatorname{tg}_1\delta = -\operatorname{tg}\varphi; \quad \operatorname{tg}_2\delta = -\operatorname{tg}\varphi - \frac{1}{n_2\cos\varphi}. \tag{15}$$

The second solution in (14) and the first in (15) are not dependent on the factor n_2, but only on local latitude. Therefore, with any values of the factor n_2 the constructed curves will emanate from two points with the coordinates $t = 0°$, $\delta = \varphi$ and $t = 180°$, $\delta = -\varphi$.

For convenience in constructing curves using formula (13) it is necessary to determine the value of the hour angle $t = \lambda$, for which $\operatorname{tg}\delta$ has one value. For this we equate the radicand in (13) to zero, and as a result we obtain

$$\cos\tau_{12} = \pm\sqrt{\frac{4n_2(n_2 + \sin\varphi)}{4n_2(n_2 + \sin\varphi) + 1}}. \tag{16}$$

For these two values of the hour angle $t = \tau_{12}$ we use formula (13) to determine the corresponding δ_{12} values:

$$\operatorname{tg}\delta_{12} = \frac{(2n_2 \sin\varphi + 1)\cos\tau_{12}}{2n_2\cos\varphi}.$$

Simultaneously from expressions (13) and (16) it follows that the curves are situated in two intervals of hour angles $0° \leqslant t \leqslant \tau_1$; $\tau_2 \leqslant t \leqslant 180°$ and in each interval will have two branches emanating from points with the coordinates τ_1, δ_1 and τ_2, δ_2. In the figure in the indicated intervals for a local latitude $\varphi = 60°$ and factors $n_2 = 0.707$ and $n_2 = 1$ using formula (13) we constructed curves denoted $\sigma_A(\lambda) = 0.707\sigma_\lambda$ and $\sigma_A(\lambda) = \sigma_\lambda$ respectively. With tie-in to celestial bodies with equatorial coordinates situated on the depicted curves, the special mean square errors of the computed azimuth in dependence on the mean square errors in determining local longitude are characterized by the expressions

$$\sigma_A(\lambda) = 0{,}707\sigma_\lambda; \quad \sigma_A(\lambda) = \sigma_\lambda.$$

respectively.

For celestial bodies with equatorial coordinates situated outside the constructed regions the special errors in the computed azimuth will satisfy the following conditions:

$$\sigma_A(\lambda) < 0{,}707\sigma_\lambda, \quad \sigma_A(\lambda) < \sigma_\lambda.$$

We note that the constructed nomogram reflects the equatorial coordinates of celestial bodies situated in the western celestial hemisphere if the observer is situated within the sphere and in the eastern celestial hemisphere when the observer is situated outside the sphere.

It follows from the cited nomogram that a lesser error in determining azimuth in the northern hemisphere is obtained in the case of a tie-in to celestial bodies situated in the northern part of the celestial sphere, since in it the regions enclosed by the curves $\sigma_A(\varphi) = 0.707\sigma_\varphi$ and $\sigma_A(\lambda) = 0.707\sigma_\lambda$ occupy extremely small areas. Similar nomograms are constructed using a digital computer for other latitudes in the intervals $\varphi \sim 10°$.

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ESTONIAN ACADEMY OF SCIENCES GENERAL MEETING

Tallin SOVETSKAYA ESTONIYA in Russian 31 Mar 77 p 3

/ETA article: "Raising the Efficiency of Research"/

/Text/ The Estonian SSR Academy of Sciences general meeting was held on 30 March in Tallin where the results of work in 1976 and the tasks for the second year of the Tenth Five-Year Plan were discussed.

The meeting was opened by President of the Estonian SSR Academy of Sciences K. Rebane. "One of the key issues, facing our national economy in the Tenth Five-Year Plan," he said in his introductory speech, "is the acceleration of the scientific and technical progress. Wide assimilation of advanced equipment and technology and reconstruction of production on the basis of a unified technical policy are the main factors of increasing labor productivity and the efficiency of production. This makes the question of strengthening the ties between science and production especially urgent, as General Secretary of the CPSU Central Committee L. I. Brezhnev emphasized once more at the meeting with the chief executives of academies of sciences of socialist countries."

"Today's meeting is called upon to sum up the results of our work and to outline further constructive ways of fulfilling the tasks, set before scientists by the 25th CPSU Congress."

K. Rebane dwelled on the activities of the Estonian SSR Academy of Sciences scientific institutions within the limits of 12 complex research programs. Most of these programs are included directly in corresponding programs of the USSR Academy of Sciences or the USSR Council of Ministers State Committee for Science and Technology. This makes the scientists of the republic especially responsible for the thoroughness and quality of research and its timely completion.

Chief Learned Secretary of the Presidium of the Estonian SSR Academy of Sciences A. /Kyoyorna/ made the report about the academy's activities in 1976 and the plan of research for 1977.

"The 25th CPSU Congress," he said, "has deemed it necessary to concentrate the attention of scientists on the most important problems of science, technology, and social progress, on which in many respects depends further successful development of our economy, culture, and science itself. The decisions of the congress compel us to raise the efficiency and quality of scientific research, ensure further improvement of the forms of relationship between science and production, and accelerate introduction of scientific achievements into the national economy."

"The collectives of the Institutes of Cybernetics and Economics, and also of the SKB /Special Design Bureau/ of the academy have appealed to all scientific institutions of the Estonian SSR with a request to activate the role of scientists in the increase of the efficiency of research and in the introduction of its results in practice. In response to this the institutions of the Estonian SSR Academy of Sciences have taken upon themselves additional stepped-up socialist pledges."

"Last year the academy managed to obtain significant results in the resolution of urgent theoretical and practical problems. The drafting of all 17 themes, anticipated by the plan, has been completed, 30 projects were submitted for realization in practice. Noted among the most important research projects of the USSR Academy of Sciences were the results of 19 works completed at the Academy of Sciences of the Estonian SSR. Among them: a model describing the process of appearance of galaxies with a spiral structure, analyses of clouds of the mesosphere, of the luminescence of crystals, and so forth."

"A new way of determining the properties of complex organic molecules and molecular structures by the method of nuclear magnetic resonance in solids and a model of correction based on the express-analysis of a cast of secondary raw materials at the enterprises of nonferrous metallurgy were developed and assimilated. A new protective film for coating semiconductor structures was synthesized, and a method, permitting to determine the electrophysical properties of semiconductors through their electroluminescence, was developed. A sounder for determining the temperature, electric conductivity, pressure, and the quantity of dissolved oxygen in Baltic waters was created and used in expeditions, and the first expeditions of the vessel "Ayu-Dag" of the Academy of Sciences of the Estonian SSR were carried out."

"Scientists have achieved good results in social science. A complex of works on the economics of the environment was published. A number of recommendations concerning the development of the republic's productive forces was submitted to the Estonian SSR Gosplan. A monograph on "The Great October Socialist Revolution in Estonia" was published, a dictionary of the Estonian language was put out, and so forth."

"However," remarked the speaker, "while evaluating the results of work in the past year, one cannot but note that the restructuring of activities of the institutes in accordance with the demands of the 25th CPSU Congress is being accomplished slowly. In the decrees of the CPSU Central Committee on the performace of the Academy of Sciences of the Ukraine and the Siberian Branch of the USSR Academy of Sciences once more the attention has been focused on raising the responsibility of the executives of scientific-research institutions and scientists for the quality of research, on the concentration of efforts on the main ways of scientific and technical progress."

"The Presidium of the Academy of Sciences of the Estonian SSR has concretized the list of key complex programs--the basis of the academy's activities. Included among them are such, as "The Semiconductor Heterojunctions," "Complex Utilization of Phosphorites," "Complex Utilization of Schists," and so on. The academy's institutions will take part in the republic agricultural programs. Academic program "Biological Foundations of Increasing the Productivity of Plant Growing and Animal Husbandry" has been put together and approved."

"It is impossible to overestimate the importance of multifaceted relations with the USSR Academy of Sciences and the academies of sciences of Union republics for the Academy of Sciences of the Estonian SSR, for science in all of Soviet Estonia. As the depth and outcome of fundamental research grow and on this basis appear ever more significant results for practical implementation, the contacts with industrial ministries and organizations, with their scientific institutions are also getting stronger. During the past year 30 different important All-Union and international conferences and symposiums were held in the republic."

"In 1977 the main emphasis in the work of the Estonian Academy of Sciences is placed on the development of fundamental research, on the realization of complex programs. Thus, scientists of the department of physicomathematical and technical sciences will work according to the programs of semiconductor heterostructures, problem-oriented minicomputers, automated control systems, and so on. There are 90 themes in the plan of the department of chemical, geological, and biological sciences. Among them are the development of new methods and apparatus to determine the physicochemical properties of organic combinations, participation in the compilation of a prognostic map of supplies of phosphate raw materials on the territory of the USSR, generalization of the results of research of the flora and fauna of /Matsaluskiy zaliv/ as a preserve of international significance, a series of experiments in the field of molecular biology, and others."

"The 25th CPSU Congress has emphasized the need to pay increased attention to research in the field of social sciences. Scientists-economists of the Estonian SSR are now activating their studies in respect to many topical directions. Recommendations will be worked out in respect to determining the rate of development of services, jurists are preparing recommendations for raising the efficiency of legislation in the field of environmental protection, and historians must on the whole complete their work in research of the history of the Baltic region, which is being carried out together with the scientists of other Baltic republics and the USSR Academy of Sciences. Linguists will compile a new Russian-Estonian dictionary."

"The material and technical basis of the Academy of Sciences of the Estonian SSR will be strengthened. The construction of a new wing of the Institute of Physics is nearing completion, construction will be started of the Institute of Cybernetics' SKB of Computer Technology, of the experimental laboratory of the Institute of Zoology and Botany, and so on."

In preparation for the 60th Anniversary of the Great October Revolution, all workers of the Estonian SSR Academy of Sciences, as mentioned at the meeting, are experiencing a sense of pride for the achievements of the Soviet people, of Soviet science, and will apply all their creative energy in order to increase the effectiveness of scientific research, in order to fulfill the tasks of the five-year plan.

Academicians of the Estonian SSR Academy of Sciences G. /Naan/ and B. /Tamm/ and Corresponding Members of the Estonian SSR Academy of Sciences M. /Veyderma/, O. /Eyzen/, and Kh. /Trass/ took part in the discussions.

Elections of new corresponding members of the Academy of Sciences of the Estonian SSR were held. The new members are: Senior Scientific Member of the Institute of Physics of the Estonian SSR Academy of Sciences, Doctor of Physicomathematical Sciences V. Khizhnyakov; Director Pro Tem of the Institute of Cybernetics of the Estonian SSR Academy of Sciences, Doctor of Technical Sciences Kh. /Aben/; Senior Scientific Member of the Institute of Zoology and Botany of the Estonian SSR Academy of Sciences, Doctor of Biological Sciences, Professor /Kh. Simm/; Chief of the Sector of the Institute of Geology of the Estonian SSR Academy of Sciences, Doctor of Geological and Mineralogical Sciences A. /Raukas; Director of the Institute of Economics of the Estonian SSR Academy of Sciences, Doctor of Economic Sciences V. /Tarmisto/; Director of the Institute of History of the Estonian SSR Academy of Sciences, Doctor of Historical Sciences, Professor K. /Siylivask/; instructor of the Tartu State University, Doctor of Philological Sciences, Professor /Yu. Pe'egel'/.

The results of a contest for the best students' work were made public at the meeting and the student prize for 1977 was awarded to the 1975 graduate of the Tartu State University /Sayme Inno/.

Taking part in the general meeting of the Academy of Sciences of the Estonian SSR were: Comrades /I. Kebin, V. Vyalyas/, Secretary of the Presidium of the Supreme Soviet of the Estonian SSR /V. Vakht/, ministers of the Estonian SSR /E. Nu'ut/ and /V. Ryatsep/, Secretary of the Tallin Gorkom of the Party E. Matt, Deputy Section Chief of the Central Committee of the Comparty of Estonia P. /Yarve/, as well as the responsible official of the CPSU Central Committee G. Peregudov.

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THE SCIENTIFIC POTENTIAL OF SIBERIA

Moscow PRAVDA in Russian 17 May 77, p 3

/Article by Academician G. Marchuk, Chairman of the Siberian Section of the Academy of Sciences of the USSR, Novosibirsk/

/Text/ The 60th Anniversary of the October Revolution is a major event for Siberian scientists. The Central Committee of the CPSU has examined the role of the Siberian Section of the Academy of Sciences of the USSR in the development of basic and applied scientific research, the increase of effectiveness of such research, the introduction of scientific achievements into the national economy and the training of personnel.

While approving the activity of the Siberian Section, the Central Committee of the CPSU, at the same time, pointed out deficiencies and unsolved problems which impede further development of science in Siberia and which reduce the efficiency of the scientific potential of this region. The slow pace of development of research on the complex use of the natural resources of the Eastern regions of the country received special mention.

These problems received special attention at the general session of the Section and by Party-economic actives at all of its scientific centers. There emerged a clear-cut definition of the attempt by scientists to create, on the basis of basic and applied research, a long-term program of development of Siberia with consideration of the productive forces and the economic possibilities of the regions. This required the focusing of attention on major complex programs. Precisely such programs will provide the increase of effectiveness of science from the point of view of the realization of the long-term economic policies of the State.

As a result of the discussions, nearly 20 scientific programs ensuing from the decrees of the 25th Congress of the CPSU were suggested. They all are grouped into three sections: development of the natural resources of Western Siberia and Eastern Siberia and problems for Siberia as a whole, such as environmental protection, the complex use of forests and lumber. This is in line with elaborations of the State Plan of the USSR for further development of the economy of Siberia.

Western Siberian regional programs are aimed at the creation of scientific bases for the development here of a major petroleum and gas extraction base. Analysis of geological data indicates the possibilities of further discoveries of these resources in Tyumenskaya Oblast. Previously unknown types of deposits have been discovered and have given a new perspective on the oil resources of vast territories.

The attitude toward petroleum explorations in the paleozoic deposits of the Western Siberian platform has changed in principle. Petroleum is now being obtained from paleozoic limestones in 15 areas. The investigators had available important data concerning occurrences of such deposits in Tomskaya, Novosibirskiy and Omskaya Oblasts. Scientific preconditions existed for wide-scale petroleum prospecting at the second "level".

The two programs mentioned here are naturally associated with a third program whose purpose is the maximum participation of sicence in the establishment and operation of the Tobol'sk and Tomsk petrochemical combines: there was the need for skilled chemists and other specialists to study the structure of all varieties of petroleum of Western Siberia and to propose effective technological processes for refining them.

Several complex programs for development of the natural resources of Eastern Siberia were proposed. In the case of Krasnoyarskiy kray, this involved, first of all, further development of the Noril'sk Mining and Metallurgical Combine. The future of Chitinskiy oblast depends to a great extent upon the development of the Udokansk copper deposit accesible to the BAM /Baykul-Amur Trunk Line/ and construction of a major ore-dressing plant. Completion of this project requires participation of representatives of mining, chemical and economic sciences.

The establishment of the Ozer'sk-Oshurkovsk territorial-production complex is a step forward for Buryat industry. Here there is a need to develop the deposits of zinc, lead, and apitites and to develop the forest industry rapidly. Thus, the Ozer'sk-Oshurkovsk TPK /territorial production complex/ provides many problems for scientists of all specialties.

There is a diamond-bearing province in the Yakut ASSR. Scientists of the republic have done much to increase its output. However, this requires high rates of development of the diamond-mining industry and requires the solution of several serious scientific and technical problems.

One component of the far-reaching program of the economic development of the zone accessible to the BAM is the organization of the Yuzhno-Yakut territorial-production complex. This has become a major theme for the Yakut branch and one of the basic themes for the entire Siberian Section of the Academy of Sciences of the USSR.

A major scientific problem is the further study of the productive forces and the determination of the structure and infra-structure of territorial-production complexes of the Angara-Yenisay region. Their establishment requires an attempt at the maximum use of raw material with utilization of wastes and on-the-spot production predominantly of finished output.

The Kansk-Achinsk power complex is now being organized at accelerated rates. The lignite supplies concentrated here will provide fuel for powerful thermal electric power plants and different large-capacity power generations. The Kusnetsk Basic with its high-performance coals and actively developing metallurgical industry is also important. All of this taken together requires performance of a vast program of investigations. Dozens of institutes are occupied in such research. The unification and coordination of their efforts is a question of vital importance.

The establishment of a new petroleum and gas extraction base in Eastern Siberia is completely practicable. There are excellent prospects for deposits in the north in Krasnoyarskaya Kray, in Evenki, in the region of the so-called Nepskiy anticline of Irkutskaya Oblast. However, the complex geological-geophysical conditions of the attitude of the seams require considerable improvement in prospecting methods.

Yakutsk scientists were the first to observe natural gas in the Earth's crust in a solid state. The development of methods of prospecting and appraising such deposits may essentially supplement existing gas reserves.

The Siberian Section of the AS USSR gives constant attention to the conservation and rational use of natural resources of the Lake Baykal Basin. The major purpose is to recommend procedures for reliably ensuring normal vital activity of the non-renewable ecological system. The effect of large-scale economic activity of man requires an increase of research directed toward the protection, renewal and, where possible, the increase of natural resources. Such research is being developed actively in the Siberian Section. In addition to this, a vast biological program for satisfying the needs of agriculture is being formulated.

The All-Siberian problem of the most complete and effective use of forest reserves unifies the efforts of collectives of Krasnoyarsk, Tomsk and Irkutsk scientific centers. Valuable forest resources are concentrated in precisely these regions. Academic and sectoral organizations which can contribute much to the solution of this problem also are located here.

The next cycle of complex scientific programs involves the prospects of development of Kemerovskaya, Omskaya and Tyumenskaya Oblasts and Altayskiy Kray. All the prerequisites for this exist here.

Thus, there is a unique prospect for development of the natural resources of Siberia. Academic science should give special attention to basic research in consolidating means of development of Siberian regions. This theoretical search is a component of the activity of institutions of the Academy of Sciences of the USSR. It must be directed to the creation of works in progress, constantly reinforcing and feeding major national economic projects.

Considerable experience in complex, programmed, systems approach to research and to its organization has accumulated in the Section. However, after the 25th Congress of the CPSU, it entered a new phase. Problems posed by the Congress on the development of Siberia are of vital importance to the entire country. This means that each achievement of science in this direction develops into a common public matter. In essence, scientists of the Academy of Sciences of the USSR working in Siberia were given such a responsible "social order" obligating the cooperation of specialist of practically all areas of science. First of all, it requires the unification of the efforts of institutes, divisions and laboratories of the Siberian Section of the Academy of Sciences of the USSR and then the gradual involvement of sectoral organizations, colleges, oblast, kray and republican institutions. Such cooperation provides a reliable basis for the concentration of the efforts of scientific institutions of Siberia regardless of their departmental membership and a means for increasing the quality and accelerating the rate of research.

The integration of science and education will assist in ensuring the rapid training of specialists of scientific specialties for the rapidly developing industry of Siberia where completely new productions are being established and technolgical processes are being realized. The system of interaction of science and education being developed at the Novosibirsk Scientific Center is gradually being expanded to other centers of the Siberian Section. We are obligated to support this actively. However, colleges still use the potential of the Siberian Section inadequately.

Sectoral NII /Scientific Research Institutes/ and KB /design offices/ located in Novosibirsk Academy City must play an appreciable role in the realization of regional programs. They also are presently closely associated with institutes of the Siberian Section and may, in the shortest period of time, supplement the efforts of the center with their own efforts in dealing with Siberian problems. A vital matter is the co-ordination of complex programs with State programs and cooperation with other institutes of the Academy of Sciences of the USSR, republican and sectoral academies.

The influence of Party organization certainly has a great effect upon the consolidation of the efforts of different departments.

Solution of the problems posed requires a substantial increase of the effectiveness of studies, first of all on the basis of their automation and mathematicization with the help of wide use of EVM /electronic computers/ and the improvement of scientific instrument manufacture. There are plans for specific means of increasing labor productivity of scientists and also for measures for development of the material and technical supply base and the infrastructure of scientific centers for improving qualifications of personnel, especially young personnel.

We are convinced that, in the course of realization of complex programs, it is possible to ensure the rapid application of scientific results to practical use. It is resolved to continue the introduction of the self-justifying principle of "output by sector". Thus, complex programs promise to become an important means for strengthening the union of science and practice.

During the 20 years of its existence, the Siberian Section has developed significant scientific potential. The establishment here of schools in the leading scientific trends, the high level and the wide range of investigations all indicate the maturity of the section and its readiness to solve scientific problems which determine the future of Siberia.

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